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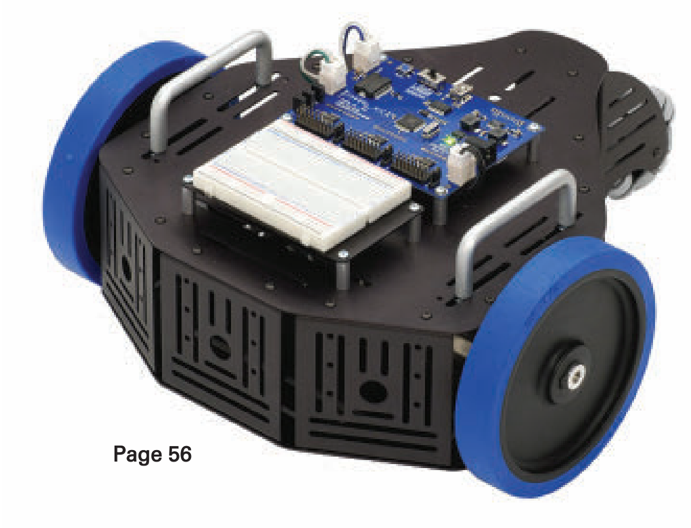

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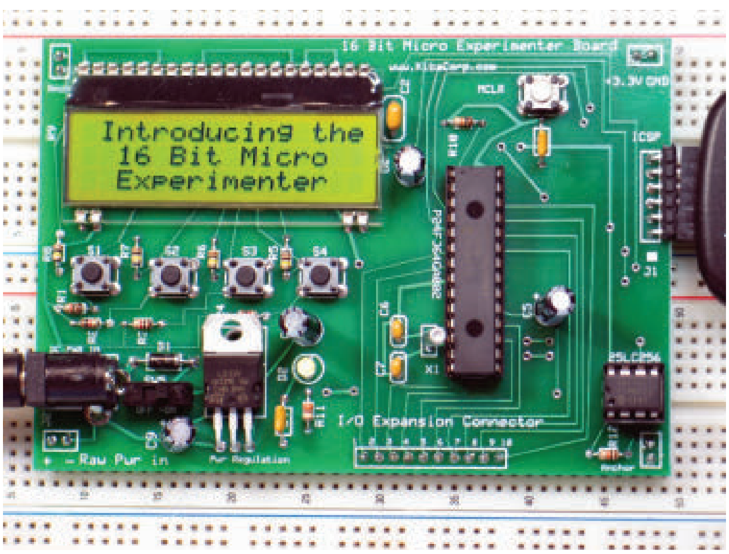

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

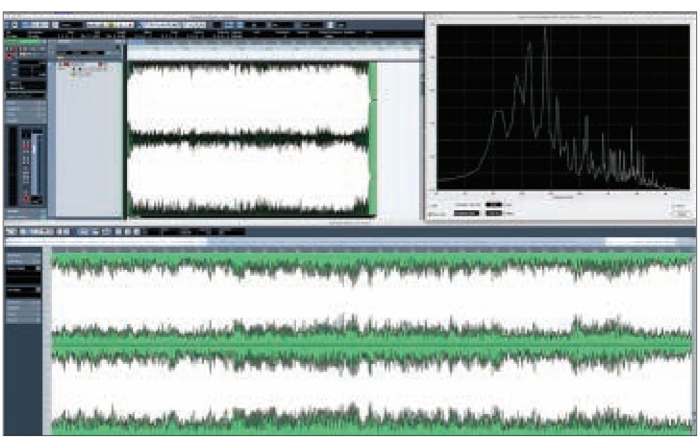
DAW Software as Instrumentation

One of the most frequent topics of email I receive from readers is how to set up a workbench, including a list of must-have and nice-to-have instruments. Many novices have a pretty good idea of what they need, but their budgets move most items to a wish list instead of a buy list. It's often a tough call — spend $350 on a Fluke DMM or $25 on a no-name DMM and put the balance toward an oscilloscope or parts for a project. There's no right answer, of course, as it depends on personal circumstances.

In a few cases, I discovered that readers strapped for cash and scouring eBay for deals were already sitting on an array of full-featured instruments. Just about everyone has or has access to a computer with a sound card or audio input port, which means everyone has the hardware platform they need for a multi-channel oscilloscope, spectrum analyzer, AC voltmeter, noise reduction system, and more.

Thanks to the popularity of home music production, DAW (digital audio workstation) software designed for composing, recording, editing, and mixing is relatively affordable and readily available. I say 'relatively' affordable because it depends on the DAW feature set we're comparing to traditional hardware instruments. For example, a 12-channel digital oscilloscope — even one with bandwidth limited to perhaps 100 kHz — is expensive. Add to that a spectrum analyzer and a variety of digital filters to remove noise from a signal and you'd need a formidable array of stand-alone instruments to match the functionality of a typical DAW.

Examples of commercial DAW software includes Steinberg CuBase 5 ($500, Amazon), M-Audio ProTools 8 ($230, Amazon), Apple Logic Studio ($500, Amazon). Most musicians start out with 'light,' inexpensive versions of these packages, often bundled at nominal cost with a computer music peripheral, such as a USB music keyboard or control surface. There are also dozens of freeware and open source DAW programs designed to leverage the powerful DSP chips in a PC/Mac. My favorite open source DAW is Audacity (**audacity.SourceForge.net**) which is supported by a huge user community.



If you've never worked with a DAW, you might be intimidated at first. The Steinberg CuBase 5 interface (shown in the accompanying photo) is representative of high-end, professional-grade, feature-packed DAW software. The screenshot (taken on my Mac) shows perhaps 1% of the available tools and windows. What is shown is simply a dual-channel amplitude envelope and spectrum analyzer window. Of particular note are the spectrum analyzer controls for spectrum analysis bandwidth, precision, and whether the display is in dB or simple amplitude. There are a dozen additional parameters that can be adjusted from drop-down menus to adjust the spectrum analyzer display.

The challenge — and fun — in using a DAW like Cubase 5 for general instrumentation is figuring out exactly what you have and how to apply it. The spectrum analyzer and amplitude envelope windows are simple enough, but what about more advanced features which don't have parallels in traditional instruments?

A feature that I've been exploring recently is the software's ability to dynamically shift the key of a voice or other sounds, without distorting the sound appreciably. This is the same functionality available with Antarestech's industry-standard Auto-Tune (**www.antaretech.com**) pitch correction software.

My first attempt at using the Cubase 5 off-label was to down-convert sounds from an ultrasonic transducer. My goal wasn't listening to insects communicate or diagnosing engine problems — which are areas worth exploring with pitch shifters — but gaining a subjective measure of the ability of a particular ultrasonic measurer to work in a high ultrasound noise environment. It's one thing to see the tracing from an elevated noise floor on an oscilloscope and quite another to experience the signal-to-noise ratio with your own ears.

If you're using a DAW as a substitute for a standard workbench instrument or as an exploratory platform into new instruments, please consider sharing your experiences with other readers. **NV**

NUTS AND VOLTS

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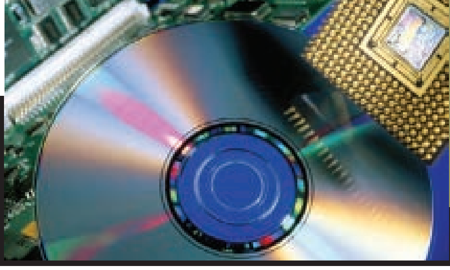


TECH KNOWLEDGEY 2009

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

JUST ADD LITHIUM ...

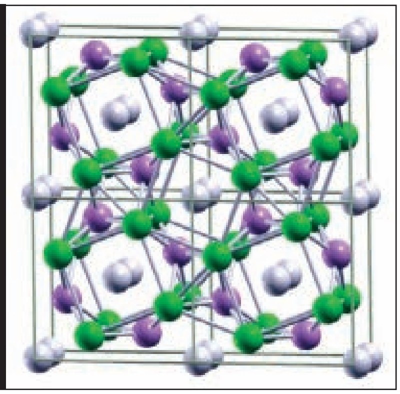


PHOTO COURTESY OF EVA ZUREK, DEPARTMENT OF CHEMISTRY, STATE UNIVERSITY OF NEW YORK AT BUFFALO.

■ Ball-and-stick image of predicted metallic lithium-hydrogen crystal cells.

For many years, the achievement of high-temperature superconduction has promised to provide huge energy savings, lower life-cycle costs for power equipment, cheaper and smaller propulsion systems for cruise ships and freighters, advanced supercomputing, and many other benefits. Of course, for almost as many years, my brother-in-law has promised to return my lawn mower. No one can be sure which breakthrough will happen first, but a team of scientists from Cornell University (**www.cornell.edu**) and the State University of New York at Stony Brook (**www.sunysb.edu**) may have put the former on a faster track.

Apparently, metallic hydrogen is predicted to be a fantastic high-temperature superconductor, but the catch is that it takes about 3.4 million atmospheres of pressure to squash hydrogen into a metallic state which is not achievable in the lab. But the researchers are predicting that if a small amount of lithium is added to the hydrogen, one could produce a stable, metallic LiH6 compound using one fourth of the pressure.

"Interestingly, between approximately 1 and 1.6 million atmospheres, all the LiH combinations studied were stable or metastable, and all were metallic," said Roald Hoffmann, co-author of the related report and recipient of the 1981 Nobel Prize in chemistry.

One problem is that LiH6 decomposes quickly at normal pressures, forming LiH and H2, but they're working on that. "We have already been in touch with laboratory experimentalists about how LiH6 might be fabricated, starting perhaps with very finely divided forms of the common LiH compound along with extra hydrogen," said Neil W. Ashcroft, co-author.

Unfortunately, that could take a while, but at least the team members have opened "the exciting possibility that nontraditional combinations of light elements under high pressure can produce metallic hydrogen under experimentally accessible pressures and lead to the discovery of new materials and new states of matter." Interesting, but I'm betting on the lawn mower. ▲

PHOTO COURTESY OF HARVARD UNIVERSITY.

■ Artist's conception of a robotic bee, created as part of the Harvard RoboBees Project.

A $10 MILLION BUZZ

A multidisciplinary team of computer scientists, engineers, and biologists based at Harvard's School of Engineering and Applied Sciences (**www.seas.harvard.edu**) have received a $10 million National Science Foundation (NSF) Expeditions in Computing grant to develop RoboBees — a prospective colony of small-scale mobile robotic devices. The project aims at nature-inspired research that "could lead to a greater understanding of how to artificially mimic the collective behavior and 'intelligence' of a bee colony, foster novel methods for designing and building an electronic surrogate nervous system able to deftly sense and adapt to changing environments, and advance work on the construction of small-scale flying mechanical devices." If you think that's a mouthful of mush, consider that the study is more generally intended to "open up a wide range of discoveries and practical innovations, advancing fields ranging from entomology and developmental biology to amorphous computing and electrical engineering."

Reportedly, one of the most complicated areas of exploration will be the design of bee-inspired hardware and software that control and monitor flight, sense nearby objects, and coordinate the device's decision making. This all sounds pretty vague, but the funding is spread out over five years, so maybe by 2014 we'll have some specific accomplishments. But, I'm still betting on the lawn mower. ▲

COMPUTERS AND NETWORKING

DESIGNED WITH AUTOCAD IN MIND

If you are a regular user of AutoCAD software from Autodesk (**www.autodesk.com**), you might want to take a look at Dell's new Precision T1500, billed as the world's first workstation built specifically to take advantage of the application's 2D and 3D features. The T1500 — a junior version of the family that includes the T3500, T5500, and T7500 — is described as a compact, entry-level machine geared to digital content creation, bioscience applications, and CAD work. Highlights include a choice of AMD ATI FirePro and AutoCAD-certified NVIDIA Quadro cards and the availability of IntelCore i7 processors and chipset technology with 1,333 MHz DDR3 memory. The T1500 base price starts at $949, making it affordable for nearly everyone, and runs up to $1,494 for a fatter version with more memory, more processing power, a larger hard drive, and a 19 in flat-panel monitor. Details are available at **www.dell.com/precision**. ▲

■ The $949 Dell Precision TI500 provides AutoCAD-certified 2D and 3D features.

ADAPTER SIMPLIFIES DIGITAL CONTENT SHARING

PHOTO COURTESY OF SEAGATE TECHNOLOGIES.

■ Seagate's DockStar network adapter lets you create your own cloud storage network.

There are many ways to share digital files, and a lot of us are still content with using clunky old ftp transfers and such. But if you want something slicker — and are willing to shell out a few bucks for it — take a look at the FreeAgent DockStar network adapter from Seagate. It allows a hard drive to be added to a network, allowing access to its content from virtually anywhere; files are accessible through any Internet-connected computer, as well as through a related iPhone application. It basically allows you to create your own "cloud" storage system while maintaining file security. Users can deliver linked images and video to MySpace, Facebook, Twitter, and other social net sites, and even send RSS feeds. Seagate is marketing the device as a mate to its FreeAgent Go™ portable hard drives, but it has four USB ports, so you can connect multiple drives and, presumably, devices not built by Seagate.

The catch is that you need a subscription to Pogoplug service for remote access and sharing, and the service will run you $29.99 annually after the first year. Details are offered at **www.seagate.com/dockstar**/. ▲

INDUSTRY AND THE PROFESSION

DO HOMEBOTS SPY?

In a project underwritten in part by NSF Awards CNS-0722000, CNS-0722004, and CNS-0846065, and an Alfred P. Sloan Research Fellowship, researchers at the University of Washington conducted a study to determine whether commercial household robots could become privacy and security risks. The not entirely amazing finding is "yes." Specifically, they studied the WowWee Rovio, the Erector Spykee, and the WowWee RoboSapien v2. The findings, per Tamara Denning: "Our experiments uncovered a number of vulnerabilities, some of which we deem to be quite serious, such as the possibility of an attacker compromising a Rovio or a Spykee and leveraging the built-in video camera to spy on a child in her bedroom." In addition to SSIDs and other leaked information over home WiFi networks, the researchers found that the Spykee — the least secure of the robots — is susceptible to man-in-the-middle (MITM) attacks and makes remote connections to the **spykeeworld.com** server in some configurations. The report, entitled "A Spotlight on Security and Privacy Risks with Future Household Robots: Attacks and Lessons," is copyrighted and not for redistribution, but as of this writing, you can find the author's original version at **www.cs.washington.edu/homes/tdenning/files/papers/ubicomp_robots_authors_copy.pdf**.

GIVE ME THE MONEY ANYWAY

The amount may be a drop in the bucket in an era in which trillions of dollars are tossed around like bean bags, but in a rather breathtaking example of chutzpah, former Nortel CEO Mike Zafirovski is reportedly seeking more than $12 million from the now-bankrupt company. This comes after his failure to turn the former telecom giant around after being hired to do so, and in spite of the fact that Nortel paid Motorola $11.5 million for the privilege of hiring him in the first place. The claim breaks down into a $2.4 million base salary for 24 months, $3.6 million in bonuses, $200,543.48 prorated bonus for Q3 2009, $50,000 in insurance benefits, and a $6 million annuity. And to think I felt bad about not returning a pocket calculator to a former employer.

VINTAGE MAC FETCHES $8,260

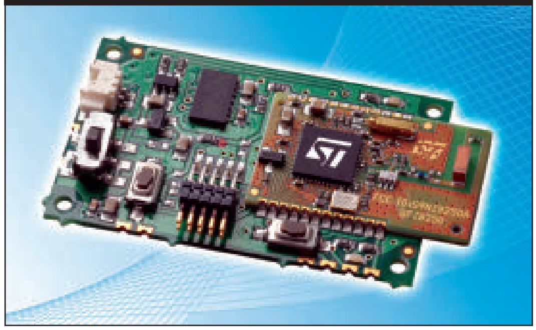
In the 1980s, the Mac Plus sold for $2,495, for which you obtained ownership of a machine that offered a 68000 processor running at a breathtaking 8 MHz, a hefty 1 MB of RAM, a 9 in monochrome monitor, and an 800 kB floppy drive. As this goes to press, there is one for sale on eBay, with the top bid holding at $33.28. And yet one recently sold at a Profiles in History auction in California for $8,260, about $7,000 more than the auction house expected. Why, you might ask? Because it was formerly owned by Star Trek creator Gene Roddenberry.

Other bits of historic memorabilia are available at **www.profilesinhistory.com**/, including a letter signed by John Adams ($29,500) and Millard Fillmore's autograph ($12,500). ▲

CIRCUITS AND DEVICES

MOTION SENSING VIA WIRELESS NET

PHOTO COURTESY OF STMICROELECTRONICS.



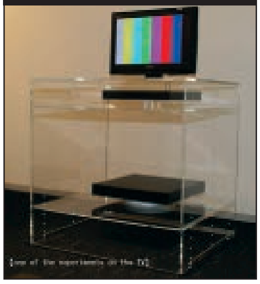
■ The MotionBee module combines motion sensing and wireless technology.

For developers of wireless sensor networks for remote recognition and tracking, STMicroelectronics (**www.st.com**) has introduced its first-gneration MotionBee™ module, dubbed the model SPMB250-A1. The unit integrates ST's three-axis digital MEMS accelerometer with a ZigBee platform from Ember Corporation (**www.ember.com**), which includes the EM250 system on a chip; a 2.4 GHz, IEEE 802.15.4 transceiver and processor; and EmberZNet PRO™ networking software. The module detects accelerations in a selectable range of ±2 g and ±6 g, and transmits data to a central connection point (using star topology) or every other node (using mesh topology) in a ZigBee wireless network.

The fully programmable module measures only 49 x 27 x 5 mm (1.9 x 1 x 0.2 in), making it applicable to wearable medical and sports equipment. It is also said to be useful in applications including security, industrial controls, and environmental modeling. The units are available now, with samples priced at $60. An evaluation kit is also offered, including two programmed modules and a ZigBee dongle for PC integration. ▲

SONY FINDS MAGNETIC RESONANCE INDUCTION

PHOTO COURTESY OF SONY.



■ Sony's prototype wireless power system.

A recent press release from Sony's global headquarters (**www.sony.net**) has caused a bit of a stir among the tech-oriented Internet sites. The release — fairly mundane in and of itself — describes a prototype wireless power transfer system that eliminates the use of power cables for television sets and other electronic products. The system has the demonstrated ability to transfer 60W over a distance of 50 cm (19.7 in) with 80% efficiency, i.e., from an 80W source. This can be increased to 80 cm (31.5 in) with the addition of a passive extender, but it presumably cannot be extended forever via additional extenders. Although the system is somewhat interesting, it would no doubt draw a yawn from Nikola Tesla, who accomplished pretty much the same thing a century ago. The fun part is that many readers have imaginatively extended the concept to the provision of wireless power to homes and factories, and are concerned that the associated electromagnetic fields might cause maladies ranging from hair loss to cancer epidemics. But I seem to recall that — at least with an isotropic source — power density drops off as the square of the distance, so if the device transfers 60W at 50 cm, you'll get only 15W at 100 cm, 3.75W at 200 cm, and so on (assuming the receiving antenna has the same capture area).

This tends to indicate that wireless power on a large scale remains highly impractical. Still, if you are the worrying type, you might want to paint yourself with rubber cement, wrap yourself in aluminum foil, and keep a metallic mesh bag over your head. Better safe than sorry. **NV**

FAN MEETS IP58 STANDARD

PHOTO COURTESY OF ERIC EISEN, JARO THERMAL.

■ A JaroTherm Aquas waterproof, dustproof DC fan. Thanks to Eric Eisen, Jaro Thermal.

Whether you need a waterproof, dustproof fan that meets IEC Ingress Protection (IP) 58 standards or simply want to spray your mother-in-law's martini in her face, JaroTherm's new Aquas™ fans will fill the bill. If you're unfamiliar with the standard, it is sufficient to note that the "58" level is the most stringent, where the "5" means "protected against dust, limited ingress," and the "8" indicates "protected against immersion."

The fans can repel water jets from any direction and withstand submersion at specified depths exceeding 1 m. They can be manufactured to meet specific water-protection requirements and come in sizes ranging from 80 x 80 x 38 mm up to 120 x 38 x 120 mm. The operating temperature range is -10° to 70° C, and their life expectancy is rated at 50,000 hr. You can get the details at **www.jarothermal.com**. ▲

#17 SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

Arduino Simple Motor Speed Control

Follow along with this series! Joe's book & kits are available in our webstore at **www.nutsvolts.com**

by Joe Pardue

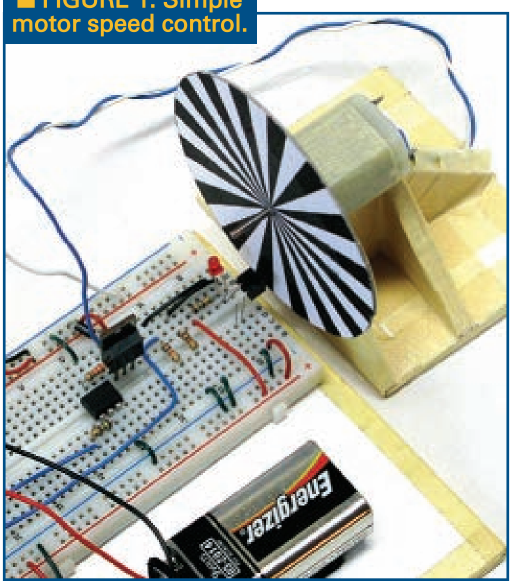
Recap

This is the last of the introductory Arduino Projects Kits Workshops. We've covered all sorts of things from 'why asking for Arduino in Milan will get you directions to a local pub,' to 'why bunny rabbits shouldn't back into dark places.' We've even learned a few technologically relevant things that will help us get going with a lot of projects we might want to do with a microcontroller, from blinking an LED to counting tomato soup cans using the Arduino Duemilanove and the Arduino Projects Kit (available from *Nuts & Volts* at **www.nutsvolts.com** and **www.smileymicros.com**). Last month, we tied up some loose ends concerning interrupts, getting numbers from a PC, and optical isolation. This month, we are going to tie it all together and learn to do some simple motor control.

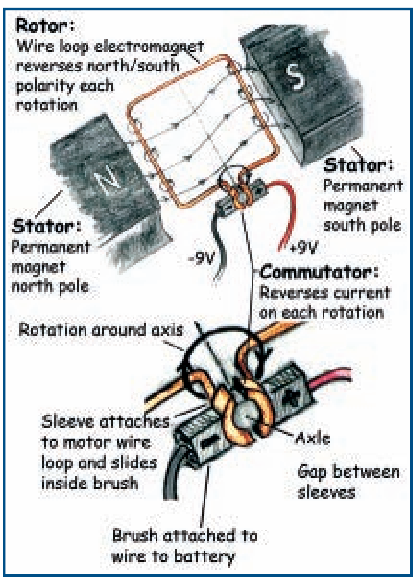
How Our DC Motor Works

In **Figure 2**, we see a simplified drawing showing how a DC motor runs. There are three main components: 1) Stator, 2) Rotor, and 3) Commutator.

The stator (as shown here) is a pair of permanent magnets that don't move (static). The rotor is a loop of copper wire forming an electromagnet that — wait for it — rotates. The commutator is a clever little mechanical device that takes the ends of the loop and flattens them on a cylindrical sleeve over the axle so that they have a gap between them (preventing the ends from short-circuiting. One end of the loop wire goes on one side of the sleeve and the other end goes on the other sleeve so that they can slide under the brushes. In the figure, the electromagnet is shown aligned with the permanent magnets, but the electromagnetic field is aligned in the opposite direction, causing the distortion in the permanent magnetic field. This means that the part of the loop to the left is the electromagnetic north and attracted to the south pole of the permanent magnet on the right, and the right side of the loop is south and attracted to the north magnet. So, the magnetic attraction/repulsion causes the loop to turn in the clockwise direction. But look what happens to the loop end sleeves on the commutator as the loop turns. The loop end that was touching the negative electric brush rotates away and comes in contact with the positive electric brush while the end that was touching the positive brush now contacts the negative brush. The current reverses in the loop causing the electro magnetism to reverse; the side that was attracted to the south magnetic pole is now attracted to the north magnetic pole. The rotation continues on around clockwise pulled by the magnetic forces until the loops nearly attain their desired goal. But the commutator again causes the current, and thus the magnetic attraction to reverse, keeping the loop spinning

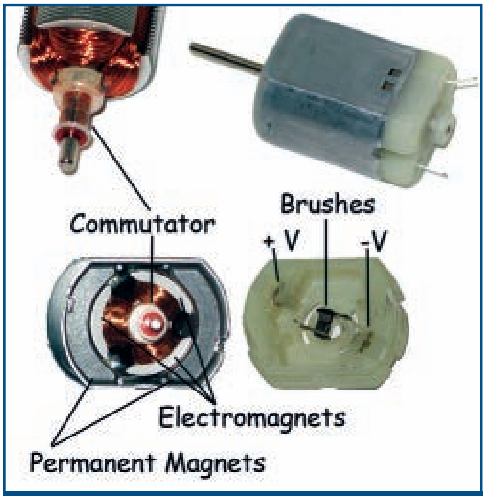


■ FIGURE 1. Simple motor speed control.

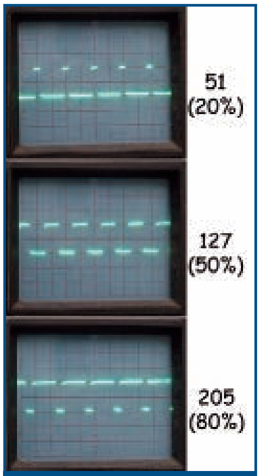


■ FIGURE 2. DC motor principles: We see a simplified drawing showing how a DC motor runs. There are three main components.

about the axle. For some reason when I was writing this, I began to wonder if maybe youthful romance doesn't have some sort of commutator that causes attraction to opposites until they get near, then find themselves repulsed and attracted to the other opposite and so on, until their axle wears out (followed by marriage, kids, debt, attempts to lube the commutator, overheating, short-circuits, nursing home ...). While this description does cover the principles of DC motors (and romance), it oversimplifies both. The commutator as drawn will short-circuit once each turn when the gaps are under the brushes. The actual motor we are using (**Figure 3**) has a three point commutator with three iron posts for the winding which not only prevents the short, but makes for better sequencing of the magnetic attractions/repulsions. (I'll forbear any more romantic metaphors, though there is often a third party involved).



■ FIGURE 3. DC motor dismantled.



■ FIGURE 4. PWMs on an oscilloscope.

Powering the Motor

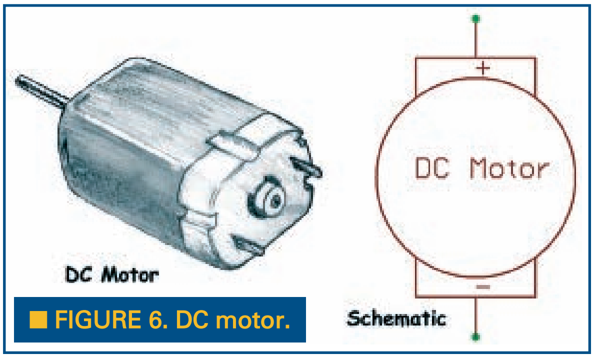
The motor in the Arduino Projects Kit is designed to run from six to 15 volts (nominal 12 volts, but nine volts is fine for our purposes) and 110 milliamps. There is a lot of slop in these figures. You can get it to turn with lower voltage or current, and it will spin happily at higher voltages or currents. Below a certain value, however, it won't turn and above a certain value it will heat up and something will break. We will use our battery as a constant (more or less) voltage source, and control the motor speed by pulsing the current with a transistor.

Every explanation I've read about how transistors work has either been too simple or too complex, so let's just accept that a tiny current on the base pin controls a much larger current between the collector and emitter pins (**Figure 7**).

Using PWM to Control the Motor Speed

We will use a Pulse Width Modulation (PWM) signal transmitted from the Arduino through an optoisolator to the base of our TIP115 transistor to make or break the connection to our nine-volt battery.

The Arduino analogWrite() function produces a PWM signal with a frequency of about 490 Hz (on/off periods per second). During each of these periods, the signal can be turned on for a part of the period and off for a part of the period. The on/off time is called the duty cycle and it can vary from 0 (fully off) to 255 (fully on), with increments in between such as 127 which sets it on half the time and off half the time (50% duty cycle). As you can see from **Figure 4**, a value of 51 sets a 20% on time for each of the cycles, and a value of 205 sets an 80% on time for each cycle.



■ FIGURE 6. DC motor.

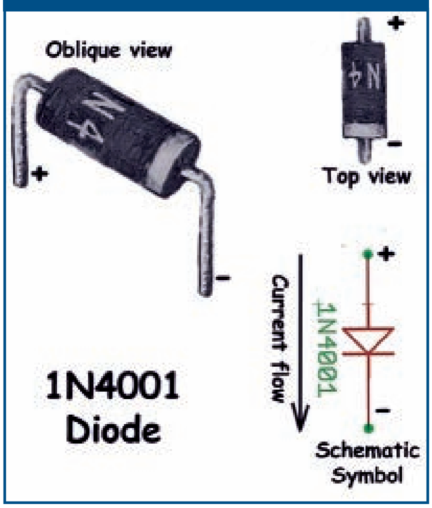
The motor (**Figure 6**) will run slower at a low duty cycle and faster at a high duty cycle, but the relative speeds are not directly proportional to the duty cycle. You need a minimum duty cycle to provide enough energy to get the motor going — in my case, sending analogWrite() a value below 25 wouldn't make it run.

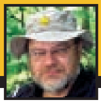
The point to take away is that you can't know the motor speed just from the duty cycle you are generating. You have to actually measure the speed and then adjust the duty cycle to fit the speed you require. We'll do this in a moment reusing the IR Detector Interrupt code from WS16. First, build the circuit shown in **Figure 8** and **Figure 9**. Test this circuit with the Arduino Fade example (discussed in WS10). If you hold the motor, you should feel it speeding up and slowing down to the same timing as the LED brightening and fading.

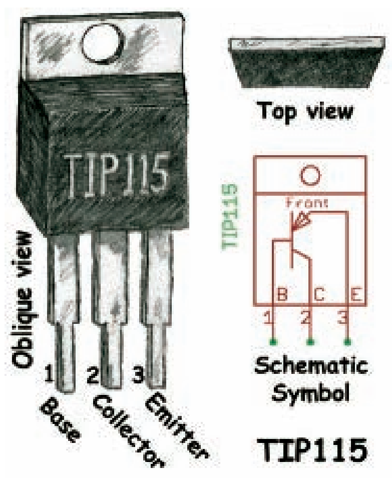
Diode to Suppress Voltage Spikes

The process involved in making the motor turn also causes the current to reverse in the copper windings every turn. One notable characteristic of coils of wire (like in the motor windings) is that once the current has started flowing, it doesn't want to stop. If you try to stop the current by cutting the wire,

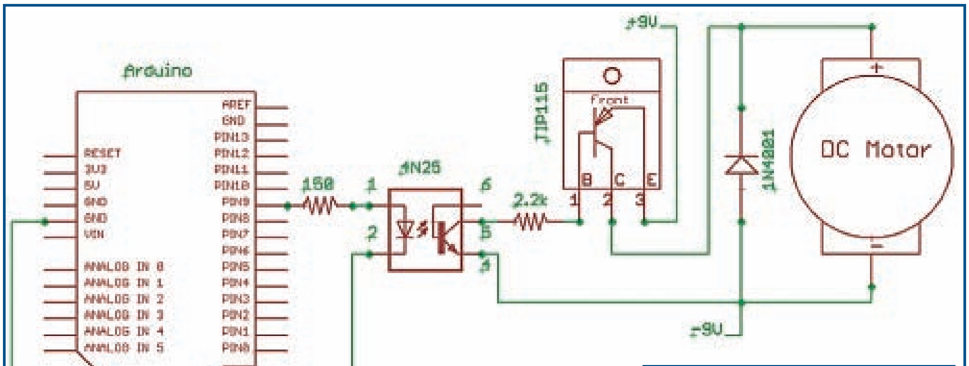
■ FIGURE 5. Diode.







■ FIGURE 7. Power transistor.



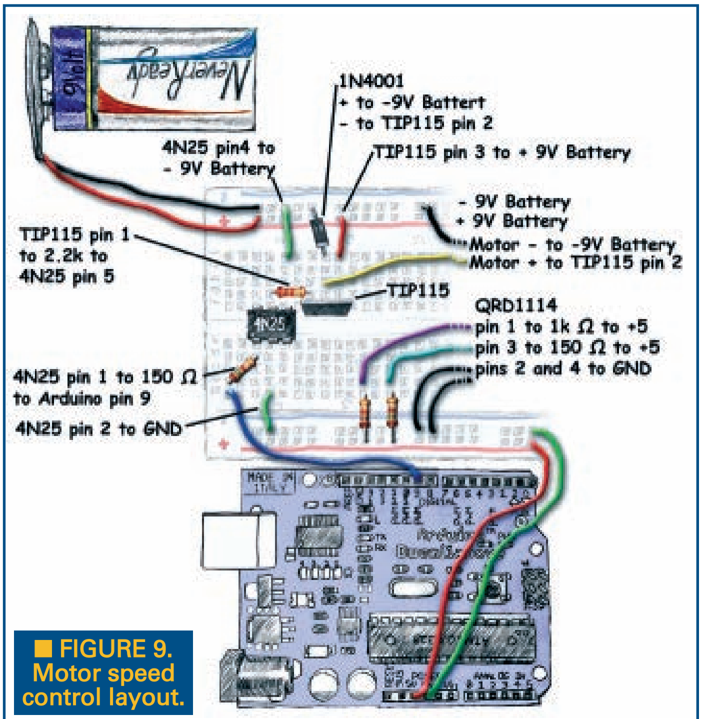
■ FIGURE 8. Motor speed control schematic.

the current will 'pile up' on one side of the cut creating a high voltage that can drive the current through the air across the cut as a spark. In the motor, the current must not only stop, it must reverse directions for each turn of the motor. This stop and reversal process generates high voltage spikes for each revolution of the motor and while an isolated motor can handle this with no problems, the voltage spikes can wreak havoc on other devices that share the same power supply. The diode shown in **Figure 8** acts like a one-way valve (as shown in **Figure 5**) so that when the current is flowing in the proper direction, the valve is off; when the current backs up, the valve opens to let it drain off the reverse surge.

Building the Breadboard Circuit

This is the most complicated circuit we will be building using the Arduino Projects Kit and, frankly, the chances of building the full circuit and writing the code from scratch and having it work correctly the first time are almost nil. You should think of this as being built from hardware/software sub-components that we've done before. First, make sure the IR detector is working properly (built and tested in WS15), and then make sure the optoisolator is doing what it should be doing (built and tested in WS16). Next, we add the TIP115 (**Figure 7**) to the optoisolator circuit in place of the LED and test that the motor speed varies in sync with the LED brightness. Only after you are sure that each part is working properly should you put the encoder wheel on the motor and try to use it to control the motor speed. This is a breadboard and something will go wrong; be prepared to take small steps and when something does go wrong, be willing to back up and verify each part of the whole.

Please note that the photograph in **Figure 1** shows the power on the opposite end of the breadboard than what is shown in **Figure 9**. I did this to simplify the circuit by showing it isolated and not mixed up with the IR detector circuitry. It shouldn't matter where you put either, as long as the QRD1114 is sticking out over the end of the board close to the encoder wheel.

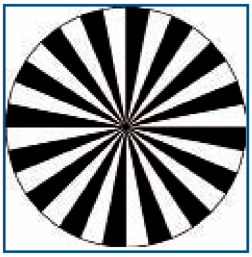


■ FIGURE 9. Motor speed control layout.

Using an Encoder Wheel to Measure the Motor Speed

We will reuse the IR reflective sensor circuit from Workshop 15 and the interrupt software from Workshop 16 to count the passing of the stripes on the encoder wheel shown in **Figure 10**. Download the pdf file of the image (Workshop17.zip) and print it on plain paper with an inkjet printer, for better IR reflectivity; darken the black stripes where they will be in front of the QRD1114 using a Sharpie© pen. Paste the disk on a piece of cardboard.

When it is dry, make a hole for the motor axle by using an X-acto knife or a scalpel (or whatever very sharp pointed thing you have handy), then slice a few 1/8" cuts in the form of an asterisk (*) at the center point of the wheel. In my case, I could slip the wheel on the motor axle and there was enough pressure provided by the cardboard to hold it in place. If yours is loose, you might want to add a touch of glue — after you've

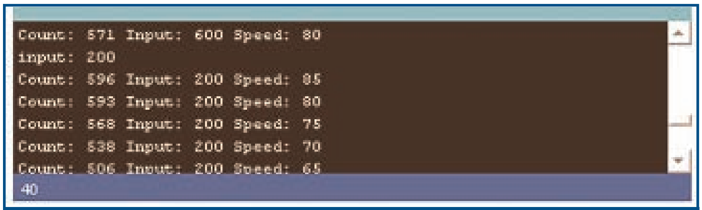


■ FIGURE 10. Encoder wheel.

made certain that the disk is both flat and at a 90° angle to the axle. You might let the glue get tacky, then run the motor while it finishes drying as the centrifugal force will align the disk properly. Play with it since a little wobble won't hurt, but a lot may make the QRD1114 readings unreliable. The motor stand was cut out of foamcore board and stuck together using masking tap and hot-glue. I eyeballed the measurements and trust that by looking at **Figure 1**, you can too.

Simple Motor Speed Control with Digital Feedback

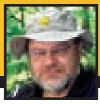
The program Simple_Motor_Speed_Control uses principles discussed in earlier Workshops (9 to 16). To set the speed, you enter a number followed by an '!'. This number will be compared to the count from the encoder wheel spinning in front of the IR detector. If the actual count is lower than the input value, then the value being sent to the PWM by analogWrite(value) will be incremented by the amount in the constant ADJUST (five, in this case). If the count is greater than the input number, the value will be decremented.



■ FIGURE 11. Program serial I/O.

You can find the maximum and minimum input values by experimenting. I noted that values of less than 125 caused the motor to stop and values greater than 1,050 maxed out the PWM value. **Figure 11** shows that entering a value of 200 for the 'Input' when the 'Count' is 596 causes the 'Speed' to decrease by five each second. When the count is close to the input, the speed will increase and decrease each second to keep the count close to the input. Even though the hardware and software are 'simple,' it serves to show the basic principles involved for one method of motor speed control.

```
// Simple_Motor_Speed_Control 8/13/09
// Joe Pardue
// This program is based on other
// Arduino code discussed in
// Smiley's Workshops 9 through 16.

#define ADJUST 5 // speed +or-

// variable to keep PWM value
```



You can find the source code and supplements for this article in Workshop17.zip at www.nutsvolts.com.

The Arduino Projects Kit

Smiley Micros and *Nuts & Volts* are selling a special kit: The Arduino Projects Kit. Beginning with Workshop 9, we started learning simple ways to use these components, and in later Workshops we will use them to drill down into the deeper concepts of C programming, AVR microcontroller architecture, and embedded systems principles.

With the components in this kit you can:
- Blink eight LEDs (Cylon Eyes)
- Read a pushbutton and eight-bit DIP switch
- Sense voltage, light, and temperature
- Make music on a piezo element
- Detect objects, edges and gray levels
- Optically isolate voltages
- Fade LED with PWM
- Control motor speed

And more ...

A final note: The USB serial port on the Arduino uses the FTDI FT232R chip that was discussed in detail in the article "The Serial Port is Dead, Long Live the Serial Port' by yours truly in the June 2008 issue of *Nuts & Volts*. You can also get the book "Virtual Serial Programming Cookbook" (also by yours truly) and associated projects kit from either *Nuts & Volts* or Smiley Micros.

```
int value = 0;
// pin for motor PWM signal
int motorpin = 9;

// variables for serial input
int myInput = 0;
int myNum[6];
int myCount = 0;

// always declare interrupt variables
// as volatile
volatile int count = 0;

// serial input converted to integer
int input = 0;

// value for PWM
int speed = 0;

// time keeping
long oldTime = 0;
long newTime = 0;

void setup()
{
   Serial.begin(9600);
   Serial.println("Simple_Motor_Speed_Control");

  // attach interrupt 0 (pin 2) to the
  // edgeDetect function
  // run function on falling edge interrupt
  attachInterrupt(0,edgeDetect, FALLING);

  oldTime = millis();
}

void loop()
{
  newTime = millis();
  if(newTime > (oldTime + 1000))
  {
    oldTime = newTime;
    Serial.print("Count: ");
    Serial.print(count);
    Serial.print(" Input: ");
```

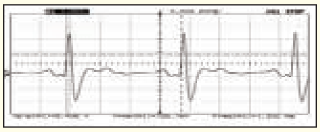
```
      Serial.print(input);
      Serial.print(" Speed: ");
      Serial.print(speed);
      Serial.println();

      if( (speed >= 0)&&(speed<=255) )
      {
        if(count < input)
        {
          if (speed != 255)
          {
            speed += ADJUST;
          }
        }
        else
       {
         if (speed != 0)
         {
           speed -= ADJUST;
         }
       }
       analogWrite(motorpin,
speed);
      }
      else (speed = 0);

      count = 0;
    }

    getNum();
    if(myInput == '!')
    {
      // convert end-of-number
character '!' to 0
      myInput = 0;
      myNum[—myCount] = 0;

      // convert ASCII string to
      // integer
      input = ATOI();

      // map the count number to
      // the PWM value
      Serial.print("input: ");
      Serial.println(input,DEC);

      // clean up and do it all
      // again
      clearAll();
    }
}

// Put serial characters in a
// character array
void getNum()
{
    if(Serial.available())
    {
       myInput = Serial.read();
       // put the character in
       // the array
       myNum[myCount++] =
myInput;
    }
}

int ATOI()
{
    // algorithm from atoi() in
    // C standard library
    int i = 0;
    int n = 0;
    for(i = 0; myNum[i] >= '0'
&& myNum[i] <= '9'; ++i)
      n = 10 * n + (myNum[i] -
'0');

    return(n);
}

void clearAll()
{
    int i;

    myCount = 0;
    for(i = 0; i < 6; i++)

    {
      myNum[i] = 0;
    }
    Serial.flush();
}

// On each IR detector interrupt
// increment the count
void edgeDetect()
{
    count++;
}
```

Well, that's it for this series on the Arduino Projects Kit used the Arduino Way. Tune in next month for more fun with AVR microcontrollers. **NV**

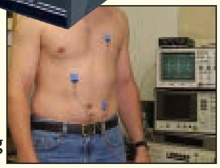
Get Ready For The Holidays With a Ramsey Kit!

Electrocardiogram ECG Heart Monitor

- ✔ **Visible and audible display of your heart rhythm!**
- ✔ **Bright LED "Beat" indicator for easy viewing!**
- ✔ **Re-usable hospital grade sensors included!**
- ✔ **Monitor output for professional scope display**
- ✔ **Simple and safe 9V battery operation**



Today, we all try to be "Heart Smart". And that usually means a healthy diet, exercise, preventive maintenance, and the knowledge of what to do... "if". Beyond that, unless you're a cardiologist, the workings of your heart are probably a mystery. Not anymore!



Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart!

Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hook-ups. In addition a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see on TV... or in the ER! See the display above? That's one of our engineers, hooked up to the ECG1C after an engineering meeting!

The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs. Operates on a standard 9VDC battery (not included) for safe and simple operation. Note, while the ECG1C professionally monitors and displays your heart rhythms and functions, it is intended for hobbyist usage only. If you experience any cardiac symptoms, seek proper medical help immediately!

ECG1C	**Electrocardiogram Heart Monitor Kit With Case & Patches**	**$44.95**
ECG1WT	**Electrocardiogram Heart Monitor, Factory Assembled & Tested**	**$89.95**
ECGP10	**Electrocardiogram Re-Usable Probe Patches, 10-Pack**	**$7.95**

42 Watt Universal Stereo Amplifier System

iPod Touch & Pink Floyd CD Not Included Those Are Mine!

- ✔ **42 watt class D amplifer, spread spectrum design!**
- ✔ **87% efficient heat-free operation!**
- ✔ **0.1% distortion for clean crisp audio response!**
- ✔ **Balanced and unbalanced audio inputs!**
- ✔ **All DC controls for noise free operation!**
- ✔ **Selectable pre/post process line outputs**
- ✔ **Short-circuit proof!**
- ✔ **Operates on 12-18VDC at a mere 3.3A!**
- ✔ **Compact and attractive shielded aluminum case!**

The success of the tiny little UAM4 stereo amplifier was incredible, but there were a lot of requests for a complete system built around its technology. These requests seemed like a great idea, so here it is, the UAM4SYS!

The amplifer is based on a single SMT device that runs in class D, which means it's highly efficient and produces very little heat! Your power goes into the audio output, not heat on a heatsink! The results, 21 watts per channel of stereo or 42 watts total or mono audio power! All cool running without the need for heatsinks or ventilation requirements! Easy-to-use board jumpers offer selectable gain of +22dB, +25dB, +29.5dB or +36dB to match your input levels. Board jumpers also enable protection and shutdown options as well as stereo/mono/bridge mode.

The amplifier also features built-in click and pop suppression to protect not only your ears and sanity, but your speakers and equipment! Line outputs are selectable pre or post processing and the headphone circuit gives you 64 steps of audio level and stores your last setting! Construction is through-hole for easy assembly, other than the SMT devices which are pre-installed. Runs on 28VDC for full rated output but runs well on 12VD for mobile applications! Visit www.ramseykits.com for complete details, specs., and accessories.

UAM4SYS	**42 Watt Stereo Ammplifier Kit With Case**	**$169.95**

Tri-Field Meter & "Ghost Detector"

- ✔ **See electric, magnetic, and RF fields!**
- ✔ **Watch the magnetic fields of the earth!**
- ✔ **Sense different magnetic poles**
- ✔ **Detect RF transmitter fields**
- ✔ **Graphical LED "sees" the invisible fields**

As Seen On CBS's Ghost Whisperer

The TFM3C has three separate field sensors that are user selectable to provide a really cool readout on two highly graphical LED bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually "SEE" these fields around you! You will be amazed at what you see. How sensitive is it? Well, you can see the magnetic field of the earth... THAT'S sensitive!

The technical applications are endless. Use it to detect radiation from monitors and TV's, electrical discharges from appliances, RF emissions from unknown or hidden transmitters and RF sources, and a whole lot more! If you're wondering whether your wireless project or even your cell phone is working, you can easily check for RF! A 3-position switch in the center allows you to select electric, magnetic, or RF fields. A front panel "zero adjust" allows you to set the sensors and displays to a known clean "starting point".

If the TFM3C looks familiar, it's probably because you saw it in use on the CBS show Ghost Whisperer! It was used throughout one episode (#78, 02-27-2009) to detect the presence of ghosts! In the electric mode, the TFM3C's displays will wander away from zero even though there isn't a clear reason for it What it was in the Ghost Whisperer was a friendly ghost. What it will be in your house... who knows! Runs on 4 AAA batteries.

TFM3C	**Tri-Field Meter Kit With Case**	**$74.95**

Popular Holiday Favorites!

FM Stereo Transmitter

- ✔ **Rock stable PLL synthesized exciter**
- ✔ **Front panel digital control and display of all parameters!**
- ✔ **Professional metal case**
- ✔ **Super audio quality!**
- ✔ **25mW kit and 1W export models!**

For nearly a decade we've been the leader in hobbyist FM radio transmitters. When it became time for a new model, we started from the ground up! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export-only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC 110/220VAC plug in power supply. The stylish black anodized aluminum case measures 5.55"W x 6.45"D x 1.5"H. and is a great match to your other equipment. *(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)*

FM30B	**FM Stereo Transmitter Kit**	**$199.95**
FM35BWT	**1W Export Only Version**	**$299.95**

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Whether you want to learn the basics of electricity, the theory of electronics, or advanced digital technology, our lab kits are for you! Starting with our PL130, we give you 130 different electronic projects, together with a comprehensive 162 page learning manual. A great start for the kids...young and old! Next, check out the PL200, that gives you 200 very creative and fun projects, and includes a neat interactive front panel with 2 controls, speaker, LED display and a meter.

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✔ Bug Zapper
- ✔ DC-to-DC Converter
- ✔ Bandpass Filter

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

WIND CHIME LIGHT SHOW

Q I am trying to create a natural light show. It is supposed to work as follows: When the wind blows, a limit switch starts a 15 second timer, which (after 15 seconds) turns on a small relay and starts a second timer, and so on for 15 timer/relays. Each relay should be on for 15 seconds but only one at a time. The big problem is how to avoid the first timer/relay turning on because of the constant wind, before all 15 timers go off.

— Roman J. Predrijevac

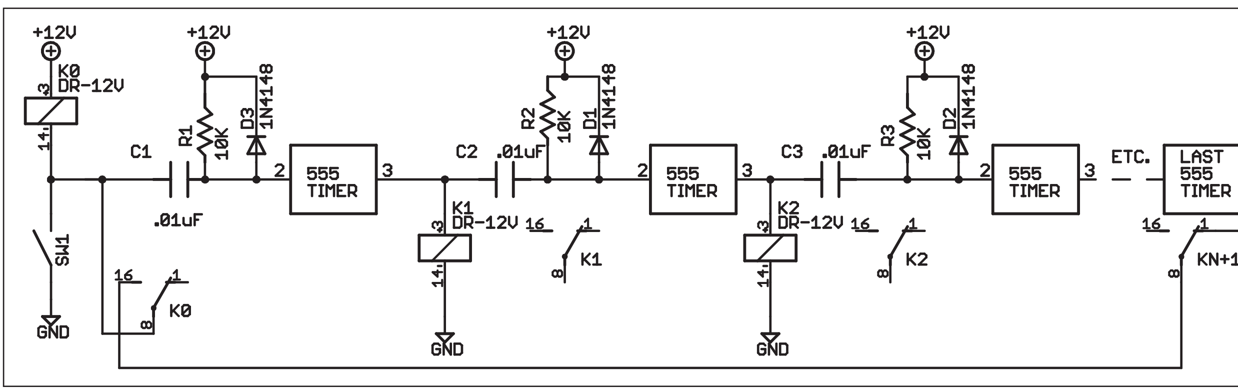
A Since you are planning on using relays, this design will also. In **Figure 1**, the limit switch (SW1) energizes K0 which is latched on through the contacts of the last relay, Kn+1. The last timer should time out in 15 milliseconds, just long enough to unlatch K0. The 555 timer will retrigger if the input is held low; that is why I used R-C coupling, so the capacitor can charge up in less than 15 seconds and prevent retriggering. The diode prevents the input from being driven above the power supply, which could damage it. You will need 17 relays because K0 and Kn+1 do not operate any lights. The 555 schematic and timing info are on the datasheet which you can find here: **www.fairchildsemi.com/ds/LM/LM555.pdf**. Jameco has a suitable relay that is economical at $1.15 each (part number 172937).

BUG ZAPPER CIRCUIT

Q I want to build an improved (energy efficient) bug zapper which operates from a small 12 VDC car battery that I can take with me camping. I want it to run all night long. I am a natural magnet for mosquitoes which I detest and do not believe are an endangered species. I want to replace the fluorescent light with alternating blinking (50% duty cycle) LEDs that are red or infrared for mosquitoes, and blue or UV for flies. I need a pulsating, nominal 5 KV circuit of about 0.1 seconds every second. I have thought of using some sort of TV flyback transformer circuit or strobe light circuit. An optional solar sensor which turns it on only at night would be desirable.

— Wally Bently

A Many people are buying LCD TVs and disposing of the old CRT based TV, so salvageable transformers are plentiful now. You can no doubt also salvage the driver transistor and other parts. I have designed the circuit such that either a bipolar NPN or N-type MOSFET can be used. The STP3NB80 is an 800 volt MOSFET available from Mouser. You may salvage the high voltage diode



■ FIGURE 1

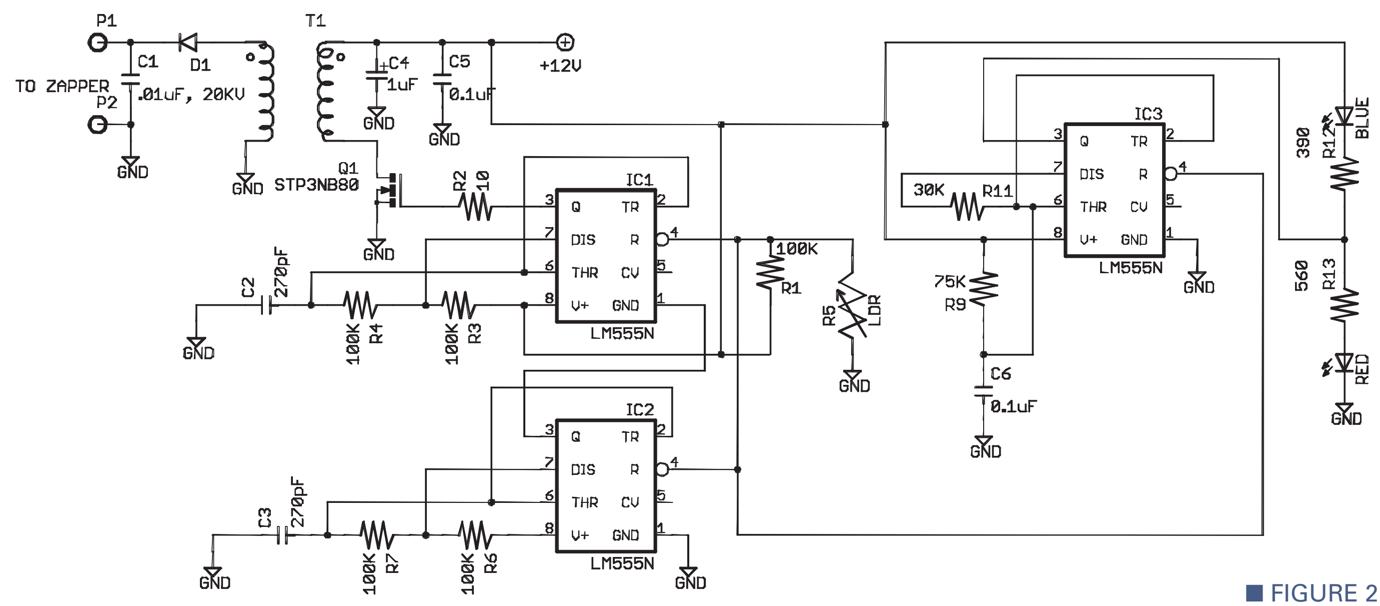


FIGURE 2

and capacitor from the TV, or they are available on eBay.

In **Figure 2**, IC1 drives Q1 with a 15 kHz signal for 0.1 seconds every second, controlled by IC2. R5 is a cadmium sulphide LDR, available from RadioShack (part number 276-1657). It pulls the reset low in the daytime to stop all action. IC3 oscillates with a 50% duty cycle to operate the red and blue LEDs. The 50% duty cycle is accomplished this way: C6 charges through R9 with approximately 0.1 mA current. When the voltage reaches the threshold, pin 7 goes low and pulls approximately 0.2 mA to overcome the current from R9 and discharge C6. This is on the verge of not working; if R11 is as high as 35K, the voltage on C6 will not go below the lower threshold and oscillation stops.

DC-TO-DC CONVERTER

Q Help! Nothing works right! I have an antique radio requiring an A/B battery of 1.5 and 90 volts. Restoring old radios is my hobby.

In reference to your DC to DC converter, June 09, page 28, I tried the LM3478 but it was just too small for me to etch and solder. I tried an LM2576-ADJ with inductor. It worked but there was too much on time and the MOSFET got hot. The 52 kHz pulse was on 25%, off 25%, and the remaining 50% was a sawtooth pattern starting at 11 volts p/p and diminishing to near zero at +6 volts average before repeating the cycle.

I then tried cycling a 555 timer at 150 kHz followed by an inverter, but it would not trigger the MOSFET even though the square wave was 12 volts. I want to use a TO-220 N-Ch MOSFET. Could you suggest a thru-hole substitute for the LM3478?

In reference to the DC-to-DC

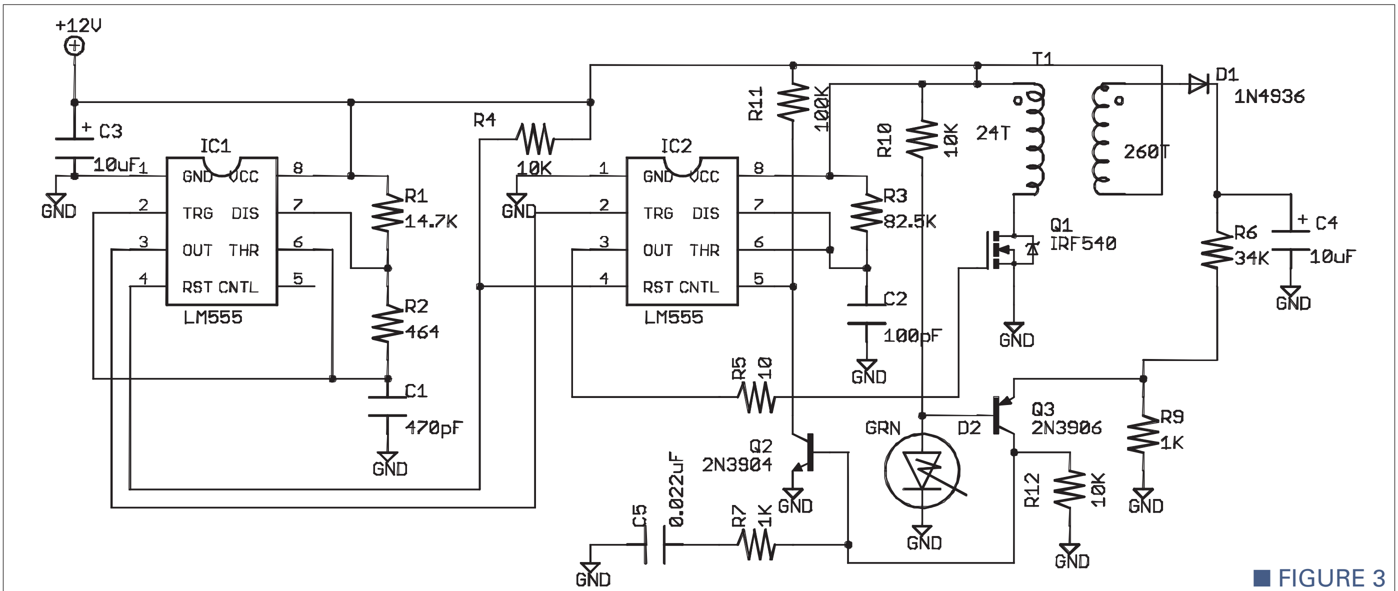


FIGURE 3

90 VOLT SUPPLY PARTS LIST

FIGURE 4

PART	DESCRIPTION	PART #	SUPPLIER
R1-R8	1/4 W, 1% METAL FILM RESISTORS	271-VALUE-RC	MOUSER
IC1, IC2	555 TIMER, DIP-8	27422	JAMECO
C1	470 pF, 50V, 5%	16109	JAMECO
C2	100 pF, 50V, 5%	16002	JAMECO
C3	10 µF, 16V, 10%	94060	JAMECO
C4	10 µF, 160V, 20%	609879	JAMECO
C5	0.022 µF, 50V, 10%	332655	JAMECO
Q1	NMOS, 100V, 27A, TO-220	210518	JAMECO
Q2	NPN, 30V, GP, 2N3904	38359	JAMECO
Q3	PNP, 30V, GP, 2N3906	38375	JAMECO
D1	400V, 1A, 200 nS, 1N4936	1559164(TO-220)	JAMECO
D2	GREEN LED, T-1 3/4	1956653	JAMECO
T1 (CORE)	CHOKE	273-104	RADIOSHACK

converter diagram, Q1 is depicted as a depletion type, but is not Q1 an enhancement type? Would either mode work?

A The symbol for Q1 was intended to be an enhancement type MOSFET even though the reverse diode — which is inherent in the device — is not shown. I don't know what a depletion type MOSFET symbol would look like.

In your LM2576 circuit, the MOSFET should have been on 25% and off 75%; I don't know why that did not happen. Perhaps the drive circuit was ringing due to long wires.

The 555 circuit should have worked; 12 volts will turn on almost any MOSFET. I have used a 555 circuit successfully, so I designed the circuit in **Figure 3**. IC1 generates a narrow pulse to set the frequency. IC2 produces a pulse which is dependent on the voltage on the control (pin 5). At power on, pin 5 is high, producing a wide pulse and high output voltage, but feedback pulls pin 5 down to regulate the DC output to +90 volts. With 1K load, (90 mA) the output of my breadboard was 89.9 VDC at 11 volts input and 93 VDC out at 14 volts input. The efficiency is 75%

Transformer construction: I used a RadioShack choke core (see parts list, **Figure 4**) because it is one of the few ferrite cores you can buy retail. I am told it is good for 500 watts but this application is 10 watts, so it's overkill. You will need a bobbin on which to wind the wire. I made a bobbin by cutting a strip 7/8 inch wide from a business card, wrapping it around a 3/8 drill bit, and gluing it to make a cylinder. I used super glue, but five minute epoxy would work also.

For the end pieces, I cut a 7/8" square from the card and punched a 3/8" hole. I found that the core was a tight fit in the bobbin, so if you make the cylinder a little loose on the drill bit, assembly will be easier. If you use the drill to center the end pieces while gluing, remove it before the glue sets or it may be glued to the drill (voice of experience).

I wound 24 turns #22 wire for the primary and 260 turns #26 wire for the secondary. A layer of tape over the primary will hold it in place while you wind the secondary. Note the small circles on the transformer symbol; they should denote the finish end of the windings if both are wound in the same direction.

The green LED is the voltage reference (about 2.2 volts). The output is determined by the R6/R9 ratio and the voltage at the Q3 emitter. You may want to tweak that ratio although the radio will work okay with ± 10% tolerance on the

MAILBAG

Dear Russell:

Re: Current Sensing Motor Control, Sept. 2009, page 32. Your column continues to be the best feature of *Nuts & Volts Magazine*. Two points regarding the subject item: You have an error in Figure 7 — the common connection from RLY1 terminals 4 and 6 should be connected to the junction of Q3 (drain) with VR1, rather than to GND. I assume that you intended that P2 be part of a two-point net connected solely to a GND symbol, with the net labeled "12V RETURN." You might advise Mr. Maslowski that there may be one instance in which depression of S1 results in no discernable mechanical movement in his apparatus. Upon power-on, the states of the motor relay and of D-flop IC1A are unpredictable, and your circuit handles this condition nicely — but all things being random, there's a 50% chance that depression of S1 following application of power may do nothing more than command the motor to run toward the direction in which it already sits. This, of course, will result in an immediate overload spike, causing IC1B to be cleared (assuming that the operator has released S1). Thereafter, IC1A and RLY1 will track each other. I have a suggestion regarding IC1B: Connect the D input to the positive rail. Move the net presently connected to input R to the CLK input instead. Connect R to the positive rail via a 1 µF tantalum capacitor and to GND via a 100K resistor. With these changes, IC1B will be initialized to the RESET state on power-on, and will toggle to the RESET state once it has been SET and after an overcurrent condition sensed. Also, it's just good practice to insert a little hysteresis in comparator IC2A: Add a few thousand ohms in series between the R5-C3+ junction and pin 3, and add a 100K ohm feedback resistor connected between pin 1 and pin 3.

— **Peter A. Goodwin**

Response: Thanks for the feedback, Peter, you are right. One of the problems of working alone is that I don't recognize my own mistakes. I did realize that at startup the flip-flops could be in either state but since it would be straightened out in the first instance, I did not consider it a problem.

Your idea of clocking IC1B is a good one; it eliminates one ambiguity from the circuit. I agree that hysteresis in the comparator is good practice; but in this case, multiple pulses during the transition will not be a problem.

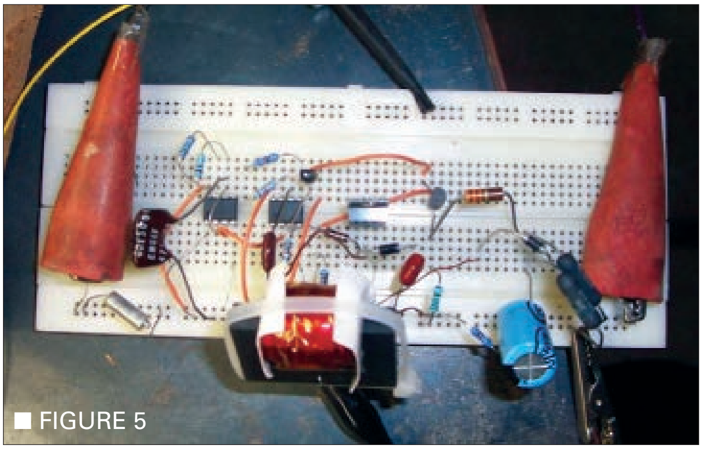


FIGURE 5

DC output. The circuit, C5 and R7, are an attempt to stabilize the circuit so it doesn't oscillate; my circuit did not oscillate and I did not use them. The 1% resistors are not actually necessary; I have standardized them because they are cheap and I don't need to have two sets of resistors.

Figure 5 is a picture of my breadboard. If that works, anything you build should work!

BANDPASS FILTER DESIGN

Q Can you figure the values for a bandpass filter using LC components? My proposed schematic is **Figure 6**. One filter passband is 190 to 199 kHz; the other is 201 to 210 kHz.

— Craig Kendrick Sellen

A The standard Butterworth filter is designed to operate between resistive source and load, so I chose a plate resistor for VT1A that would give 200 kHz bandwidth (47K). The transformation for the first filter gave a value of 1.15 picofarads for the series coupling capacitor. That is not a practical value, plus the series inductor is 584 mH which will have stray capacitance that will screw up the response. The bandwidth is too narrow.

I see that you are trying to make a stagger tuned bandpass with the two filters tuned to different frequencies. That would work, but since the filter can't be built, it would be better to combine the filters to be the same, then widen the band width because the -3 dB point of each filter becomes the -6 dB point of the cascaded filters.

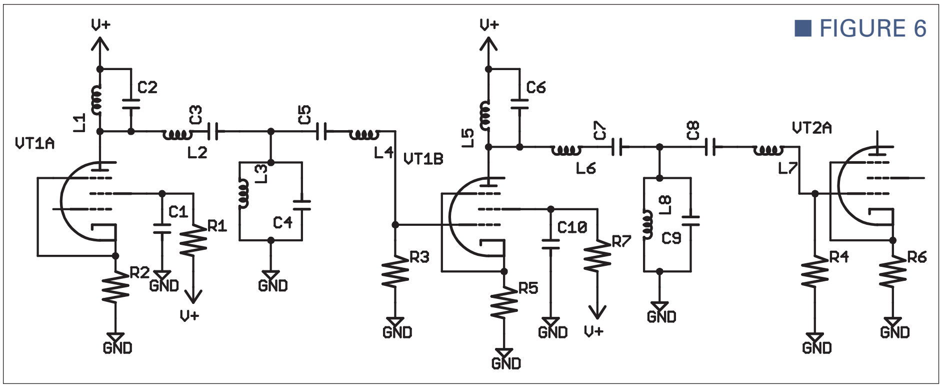
Accordingly, I designed the filter for 185 to 215 kHz. Now the series capacitor is 3.64 picofarads; still mighty small but perhaps it could work. The series inductor is 175 mH which is much easier to make. See **Figure 7** for the modified schematic.

The filter is designed for 33K source and load. The internal plate resistance of VT1A combined with the 47K plate resistor is 33K. I tried to build the filter to check feasibility but the self resonant frequency (SRF) of the 175 mH coil is 49 kHz, so that is not going to work at 190 kHz. By the way, I used Magnetics, Inc., ferrite core OF42510-EC because I bought 1,000 of them on eBay for $25.

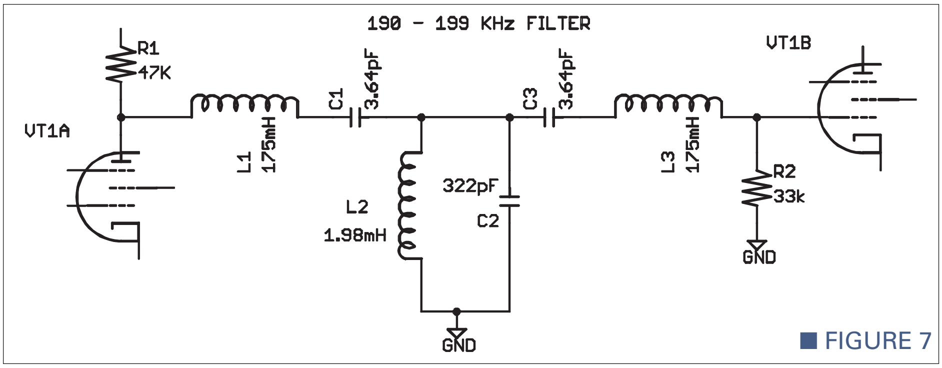
My next thought was to try a top coupled design because that is good for a narrow band; see **Figure 8**. In this design, all the coils are the same value. In **Figure 8**, the values are for the 190 to 199 kHz filter. The 201 to 210 kHz filter values are: L1 = L2 = L3 = 1.19 mH; C1 = 488 pF (208.851 kHz; C2 = 472 pF (212.361 kHz); C3 = 488 pF (208.851 kHz); and C4 = C5 = 16.6 pF.

I tried to build the 201 to 210 kHz filter. I wound the coils on the Magnetics OF42510 ferrite core. The SRF was 770 kHz which indicates a stray capacitance of 35.9 pF; that should work. The number of turns is 22 for 1.19 mH and 23 for 1.33 mH. I usually put on several extra turns and remove a half turn at a time until the inductance is just right. I put the filter together using 5% mica caps; I did not have trimmer caps so it is not surprising that my filter was not perfect. The center frequency was 204 kHz; the theoretical center is 205.5 kHz. The filter did not have a flat top but I think proper tuning would fix that.

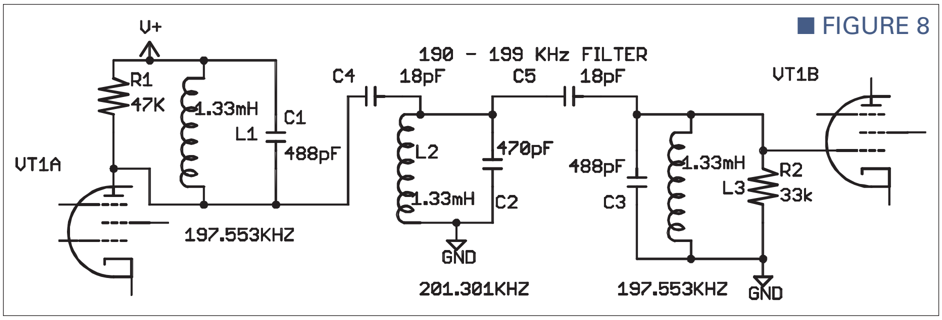
The way to tune the filter is to resonate L1-C1, L2-C2, and L3-C3, and then connect the coupling caps. A sweep generator and scope are necessary to tweak the filter to perfection. **NV**



■ FIGURE 6



■ FIGURE 7



■ FIGURE 8

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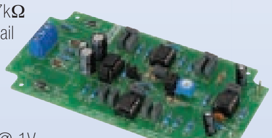

- Input impedance: 47kΩ
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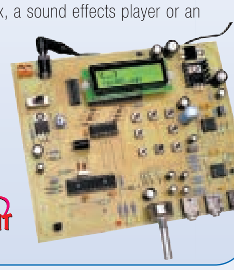
NEW KIT



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- Requires: PSU (KC-5418 £6.00) and toroidal transformer

NEW KIT

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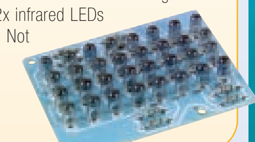

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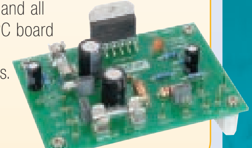
MORE INFO AVAILABLE ONLINE



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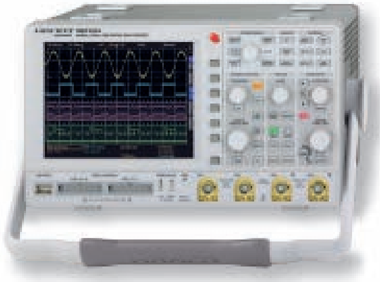

- ☑ 4 GSa/s Real time, 50 GSa/s Random sampling, low noise flash A/D converter (reference class)
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- ☑ MSO (Mixed Signal Opt. HO 3508/HO 3516) with 8/16 logic channels
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  20 div. y-axis display range with VirtualScreen function
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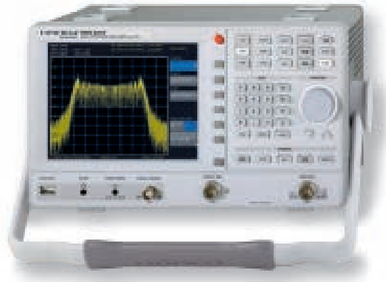
3 GHZ SPECTRUM ANALYZER HMS 3000/HMS 3010



1GHz: HMS1000 HMS1010

- ☑ Frequency range 100 kHz...3 GHz
- ☑ Amplitude measurement range -114...+20 dBm
  DANL -135dBm with Preamp. Option HO3011
- ☑ Sweep time 20 ms...1000 s
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  additional 200 Hz, 9 kHz, 120 kHz, 1 MHz (-6 dB)
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- ☑ HMP4030: 3 x 0...32 V/0...10 A, max. 384 W
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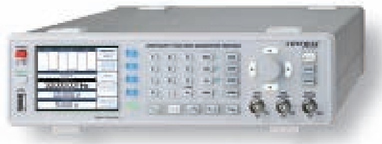

- ☑ Frequency range 10 µHz...25 MHz/50 MHz
- ☑ Output voltage 5 mV_{pp}...10 V_{pp} (into 50 Ω) DC Offset ±5 mV...5 V
- ☑ Arbitrary waveform generator: 250 MSa/s, 14 Bit, 256 kPts
- ☑ Sine, Square, Pulse, Triangle, Ramp, Arbitrary
  waveforms incl. standard curves (white, pink noise etc.)
- ☑ Total harmonic distortion 0.04 % (f ‹ 100 kHz)
- ☑ Burst, Sweep, Gating, external Trigger
- ☑ Rise time ‹8 ns, in pulse mode 8...500 ns variable-edge-time
- ☑ Pulse mode: Frequency range 100 µHz...12.5 MHz/25 MHz,
  pulse width 10 ns...999 s, resolution 5 ns
- ☑ Modulation modes AM, FM, PM, PWM, FSK (int. and ext.)
- ☑ 10 MHz Timebase: ±1ppm TCXO, rear I/O BNC connector
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- ☑ Modulation modes: AM, FM, Pulse, Φ, FSK, PSK
- ☑ Rapid pulse modulation: typ. 200 ns
- ☑ Internal modulator (sine, square, triangle, sawtooth) 10 Hz...150 kHz/200 kHz
- ☑ High spectral purity
- ☑ Standard: TCXO (temperature stability: ±0.5 x 10^{-6})
  Optional: OCXO (temperature stability: ±1 x 10^{-8})
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SCHOOL BUS Safety Upgrade

BY PAUL SHARP

I recycled a cat food can and a 4011 CMOS chip into a safety upgrade for older model school buses. As an electronic hobbyist that does electronic repair on school buses, I found it would be very helpful to be able to deploy the stop sign and activate the overhead red lights without opening the entrance door. This is a problem with older buses that have a mechanical air valve to open and close the door. The entrance door can be kept in the closed position until passengers arrive at the door. This allows the bus to stay warmer in the winter and cooler in the summer when loading the bus. When unloading the bus, it will keep the students inside until the driver determines it's safe to exit. This way, the driver can be sure the traffic has stopped.

■ FIGURE 1. The purpose of these circuits is to provide a safety upgrade to school buses.

Circuit Design

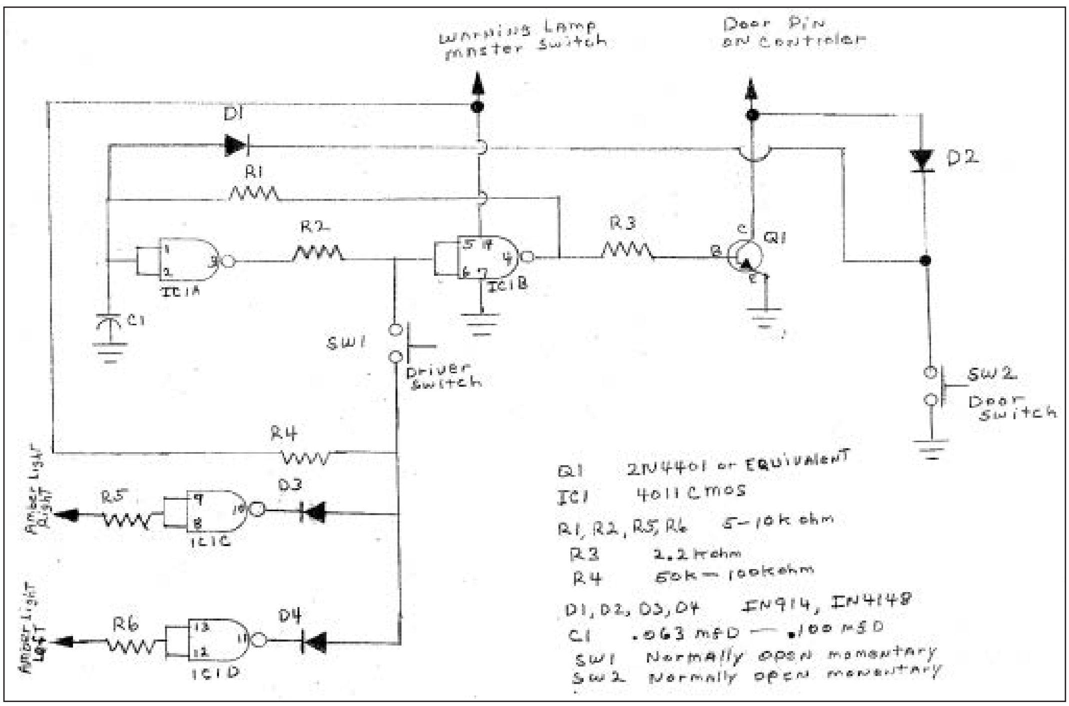
The circuit had to be as inexpensive as possible. It also had to be very easy to understand and build and install. This is why I chose the 4011 CMOS over the PIC.

By using a CMOS chip, it is fixed and reprogramming will never be necessary. The circuit will always work the same. **Figure 3** shows the circuit and how to make the connections to components on the bus.

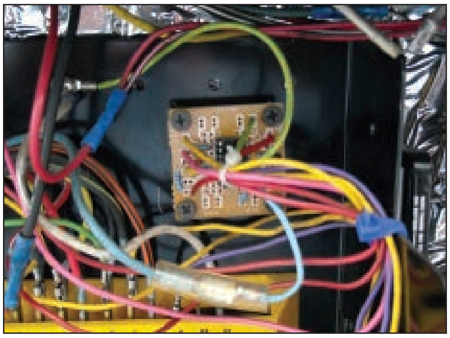
I used a universal circuit board that can be purchased

■ FIGURE 2. The circuit board with hardware to place in a used cat food can. The circuit board stand-off is made of plastic concrete anchors. A piece of high temp gasket material was used in the bottom of the can to reduce diesel vibration. Wire for the circuit is from an old wiring harness off of a junk automobile.

■ FIGURE 3. This is the circuit I used to place the stop sign out before opening the door. On older buses, the driver had to open the air door before the red lights and stop sign could be deployed. Circuit components are made of a CMOS chip and surplus resistors, diodes, and capacitors.



■ FIGURE 4. The completed assembly. The snap-on lid provides protection from insects, moisture, and dirt.



■ FIGURE 5. The working circuit mounted on the bus (without protection). The circuit was sprayed with Rust-Oleum clear coat paint to provide additional protection.

■ FIGURE 6. Placement of switch for the driver (seventh from the left).

at RadioShack. Transistor Q1 is not critical as long as it will carry enough current. Connection to the overhead amber lights prevents accidental activation by the driver before the stop sign needs to be deployed.

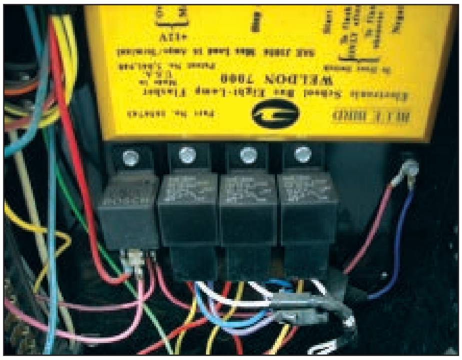
Figure 4 shows the circuit mounted in a clean cat food can. The can will provide protection for the circuit against moisture, dirt, and vibration. (Always remember to take into consideration the temperature range, nearby chemicals, moisture, and vibration when designing automotive circuits.) Gasket material was placed in the bottom of the can to help with vibration. A sealing lid was purchased at a pet supply store and provides environmental protection.

For those of you that might want to also provide wig wag headlights on the bus during the time the stop sign is deployed, I provided a circuit for that as well. See **Figure 8**.

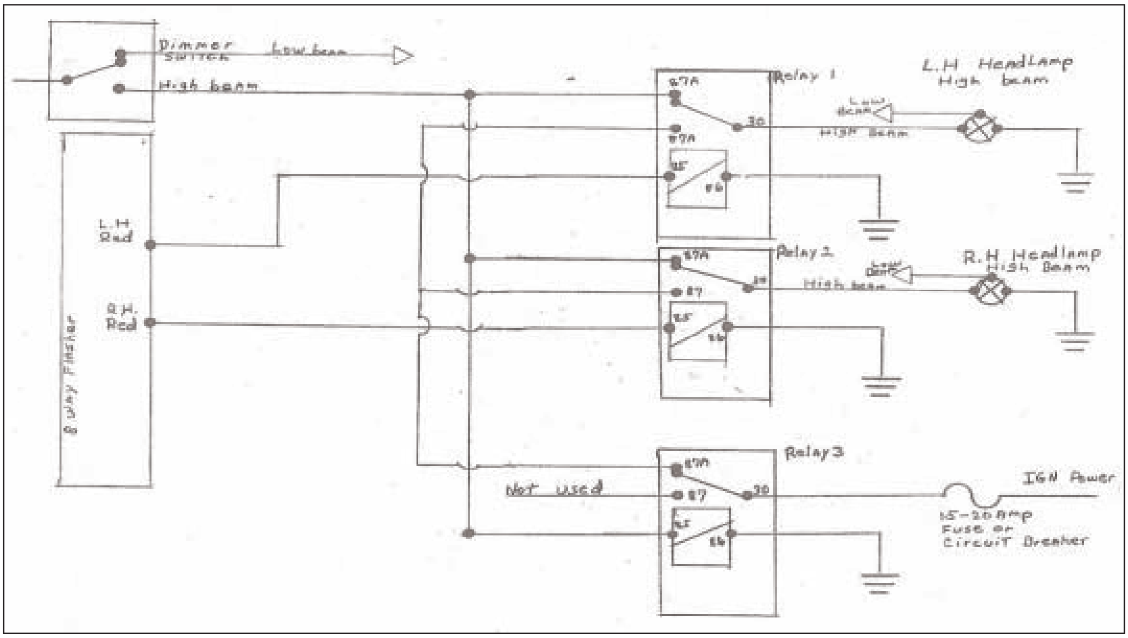
Relays for this circuit are the common 40 amp, five-pin version made by many manufacturers.

Figure 3 is the circuit I used to place the stop sign out before opening door. Drivers of older buses with an air door, driver had to open the door before the red lights and stop sign could be deployed. Circuit components are made from a CMOS chip and surplus resistors, diodes, and capacitors.

The circuit in **Figure 8** provides a wig-wag flash (alternating flash) to the headlights on high beam whenever the stop sign is deployed. This goes back to normal operation whenever the stop sign is not in use. **NV**



■ FIGURE 7. As you can see, ordinary relays are used to provide an alternating flash of the headlights on bright beam when the overhead red lights and stop sign are going. The first relay on the left is to switch the marker lights on with the headlight switch. The three to the right provide flashing headlights.



■ FIGURE 8. The purpose of this circuit is to provide a wig-wag flash (alternating flash) to the headlights on high beam whenever the stop sign is deployed. This goes back to normal operation whenever the stop sign is not used.

KEYBOARD - GAME INTERFACE

BY JOCHEN JAHN

As an avid gamer, I like flight simulators. However, I always had trouble remembering the different keyboard commands for each game. As a solution, a switchboard came to mind, with the switches activated by levers like landing gear in airplanes. I didn't want to write new DLLs or mess around with the computer. After sorting my thoughts, I got the inspiration to simulate the keyboard strokes using inputs on a microcontroller. My choice was the PIC16F877; 24 inputs were possible, so there would be plenty of features.

In order to re-program the chip with new keyboard settings, I needed an interface to the PC. Two pins on the 16F877 are used for a serial interface to the PC. The loaded data should be stored in an EEPROM — no re-loading required after power off! Two more pins are used for the I^2C communication between the PIC and EEPROM. In order to not disrupt the communication between PC and keyboard — some computers look for the keyboard at boot-up and send commands — a relay was used to switch between the board and keyboard. This allows the user to keep the board plugged in all the time (even without power on the board). The clock and the data lines to send the keyboard code took two more pins to realize. Two pins are used for the setup mode and the setup selector. Those are designed as jumpers but can be wired to switches for easy access.

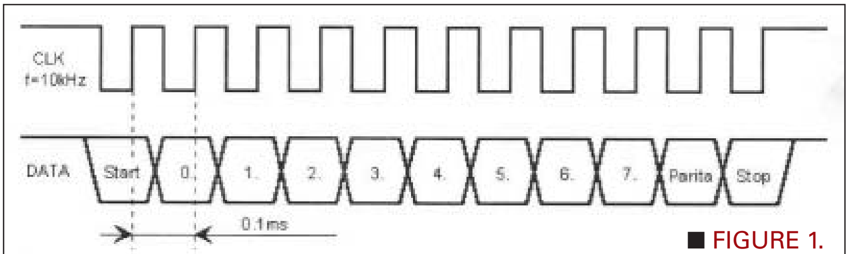
After all, all of the pins are used!

A search on the Internet revealed the code being sent from the keyboard to the PC and the data transfer (**Figure 1**). The timing is very important for the PC. The communication protocol is one start bit, seven data bits, one parity bit, and one stop bit.

Figure 2 shows the circuit diagram for the interface. The circuit fits on a single-layer, approximately 3" x 6" PCB (printed circuit board).

Let's start with the power supply. A voltage between nine and 20 volts is applied to K1. The 7805 regulates the incoming voltage to 5V with support from the two capacitors. D1 protects the circuit from reverse supply voltage. The current drawn by the circuit is between 30 and 42 mA with the relay activated; a heatsink is not required. K2 is a double terminal to bring the regulated +5 volts to the switches you want to use. The PIC's (IC1) MRCL is held up to +5 volts, with a cap working as a power-up delay. All inputs are connected to K5 via pull-down resistor arrays. You can use regular resistors too, if you can't get hold of arrays. There are 10 pin arrays: one pin for ground and nine signals. I just bend the last pin up (not the one where the dot is!). IC2 is the memory — a serial EEPROM, type 24LC16B. There are other EEPROMs that could work; I just happened to have this one on hand. You'll need at least a two Kbit EEPROM,to give us 256 bytes of storage.

Two pull-up resistors terminate the connection. IC3 is the well-known MAX232 to convert the TTL serial signals to RS-232. The programming is done through this connection at 9600 baud — good enough if you have to use a USB-to-serial interface. This IC is used in a standard configuration as (described in datasheets from Maxim). The serial RS-232 signals are routed to a nine-pin SUB-D female connector.



■ FIGURE 1.

Pin D6 and D7 on the PIC generate the clock and data signals for the PC. A relay driven by pin D5 switches the signals over to the PIC if an input changes its state and sends the data. After finishing the data transfer to the PC, the relay turns off again and reconnects the regular keyboard with the PC. K3 is connected to the PC end and K4 to

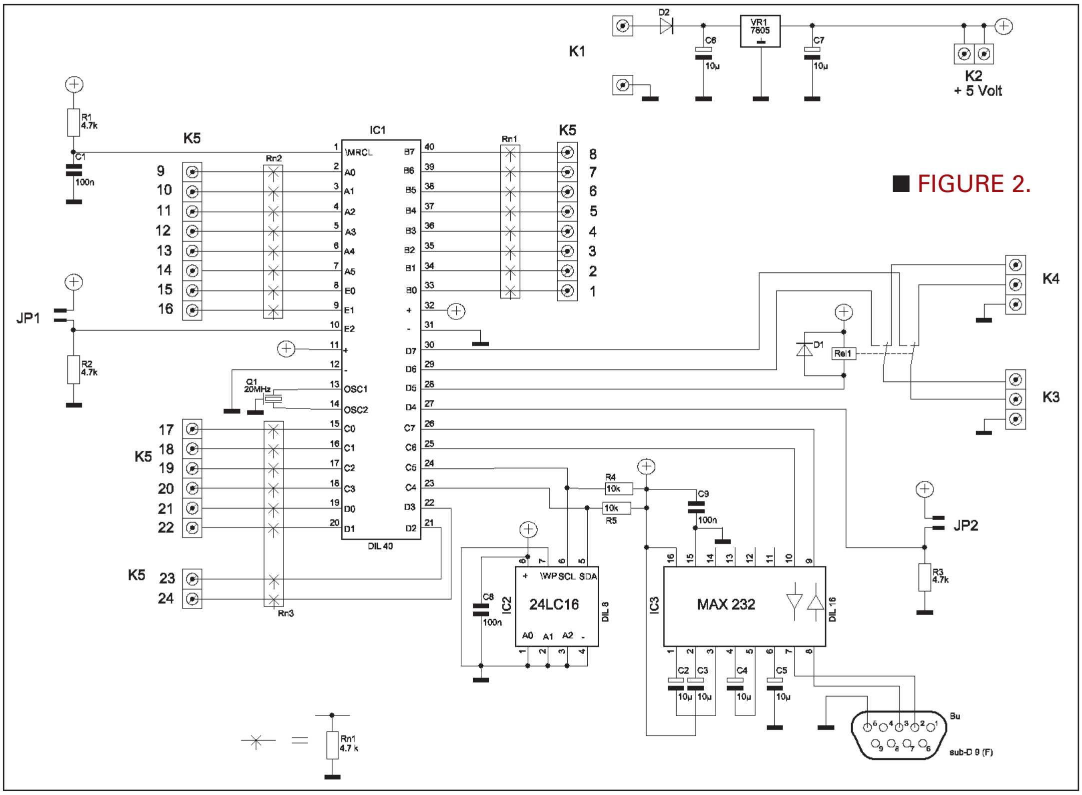
the keyboard end of the extension cable. This is just a regular keyboard extension cable I bought from a surplus store, cut in half, rung out the colors attached to the connectors, and then attached the CLK, data, and ground wire to the connector. All the other wires are reconnected with heat shrink tubing fixed. **Figure 3** shows the pinout of the keyboard connector.

The PIC is running on a 20 MHz ceramic resonator to keep the timing right for the communication via the keyboard to the PC.

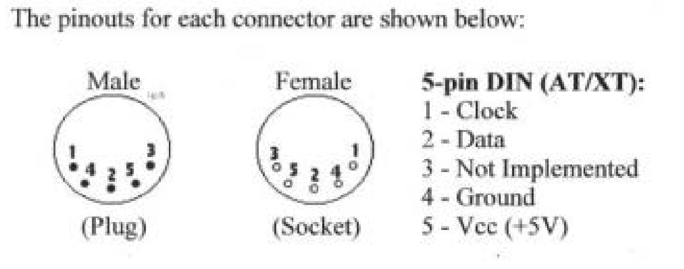
If the jumper JP1 with the attached pull-down resistor is closed, the PIC goes into the configuration mode. Without the jumper, the board scans the inputs and sends out the codes, depending on the programming. If the jumper is set, the PIC is waiting for the serial communication on the SUB-D connector. The VB6 software on the PC handles the communication and makes it possible to upload or download the setup.

There are two setups stored in the EEPROM. The jumper JP2 selects either one. The EEPROM is capable of storing more setups but I ran out of I/O pins on the PIC.

Most keystrokes send out one or two bytes for each push of a button, plus a two or three byte code for the release of a button. There are a few keys that have more bytes of code to send, but I didn't prepare the software for those. You can check the **Source** box for more information.



■ FIGURE 2.



■ FIGURE 3.

Software Stuff

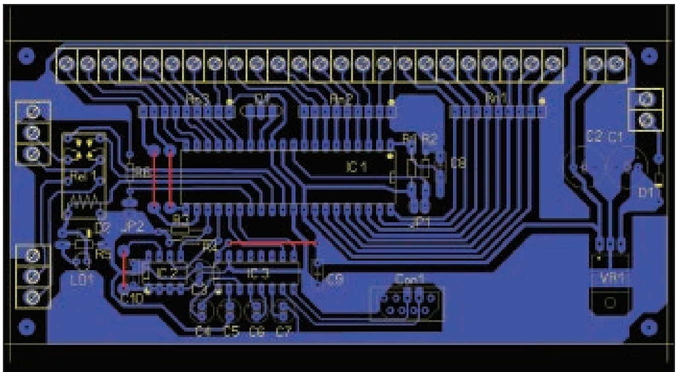
The code for example "A" is 1Chex; releasing the key generates the code F0hex 1Chex. The code for example "Pg Up" is E0 7Ahex; releasing the key generates the code E0 F0 7Ahex.

To simplify the software, I set up each keystroke with five bytes. The push codes and the release codes are independent. The PIC scans the inputs and gets the code from the EEPROM. If there are more than three bytes not equal to '00,' then it is a two byte push and three byte release code. Otherwise, it is a one byte push and two byte release code. Five bytes for each input ends up with 120 bytes of memory.

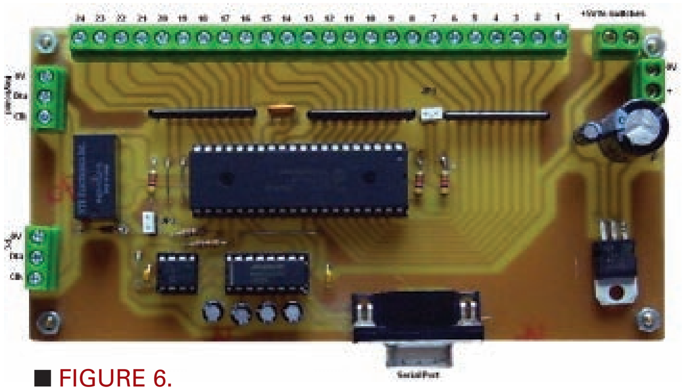
I wrote a simple VB6 software interface (**Figure 4**). On the right hand side, you have to select the correct COM port. If you use a USB-to-serial converter, the COM number might be higher than the usual 1 or 2. For example, my USB converter is set up as COM3. All found COM ports are enabled.

The following file system helps to navigate through the files for the setup to be loaded into the PIC. I used the extension *.dat for the data file. The save and load buttons are for saving a file (you can change the name), or loading the file and showing the setup on the left side of the screen. Those data are being loaded into the PIC.

The "Receive from Interface" button on the top loads the data from the PIC onto the right side of the screen. This makes it easier to do changes. The "Send to



■ FIGURE 5.

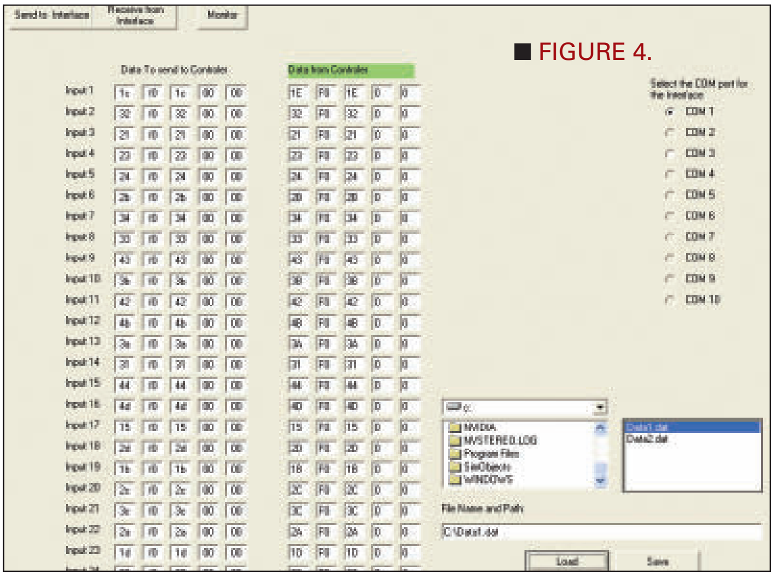


■ FIGURE 6.

Interface" button sends the information on the left hand side of the screen to the PIC. The "Monitor" button opens a banner to monitor the data transfer — just in case.

Board Assembly

The assembly of the circuit board is very straightforward. Start with the four blank wires, followed by resistors and diodes. I used only 4.7 KΩ (yellow, violet, red) and 10 KΩ (brown, black, orange). The resistor array comes next with the dot facing away from the relay. Pin 10 of the resistor array needs to be bent up or cut off. The jumpers and the ceramic resonator are soldered in place next with the IC sockets. There are two 100 nF caps and the electrolyte capacitors around the MAX232 and the EEPROM to install. The voltage regulator (7805), the nine-pin SUB-D connector, the two electrolyte capacitors, and the relay finishing the board come next. Make sure the diodes and the electrolyte capacitors are facing the right way. I used screw terminals for my board; you can use what is best suited for your application. The spacing between the terminals is 5 mm.



■ FIGURE 4.

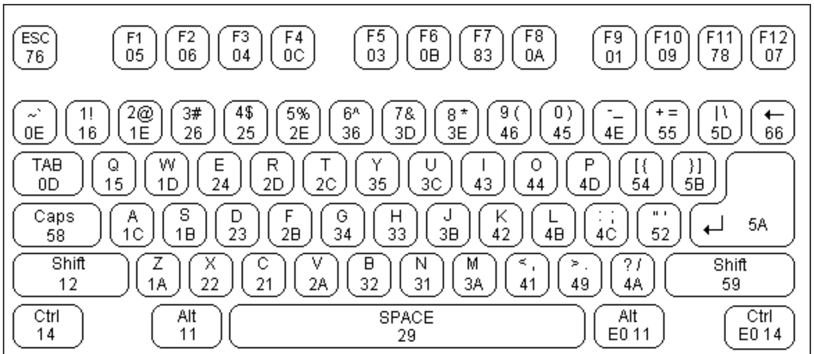
Ring out the correct colors for Data (Dta), Clock (Clk), and 0V of the keyboard extension cable and connect the female side to terminals K4 and the male side to K3. Don't forget to reconnect the other wires and isolate them.

Check the board for short circuits, bad solder spots, etc. Apply power to the board and check the current (should be a few mA). Turn the power off and insert the integrated circuits. Turn power on and check the current load again.

Set jumper JP1 and connect the board to a PC with the interface software running on it. Open the data1.dat file and load it into the PIC. This is a test file; input 1 generates an "a," input 2 a "b," etc.

Remove the jumper and give a +5 volt signal to input 1 — you should be able to hear the relay click every time you connect any input to the +5 volts. Plug in the two ends of the keyboard extension cable with the board in between. Open Notepad and touch each input again with the +5 volts. The letters should show up.

In order to select the second setup, follow the same steps as above, but with JP2 in place.



■ FIGURE A.

Time For Testing

Next, test the circuit with Microsoft's Flight Simulator 2000. If you enter the setup for the keyboard, check the settings. For example, the gear up/down. The keyboard key is "g." Check the reference (**Figure A**) for the code; '34' for push and 'F0 34' for the release of the button.

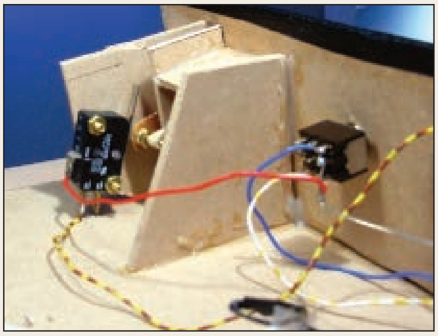
How I Built My Cockpit

■ FIGURE AA. The simulator cockpit as a prototype. In the background is the Flight Simulator 2000 running on the screen.

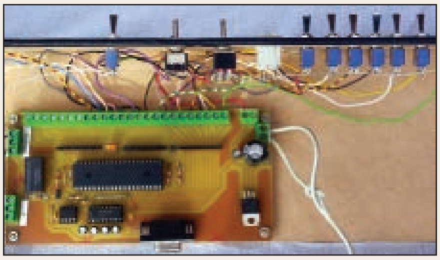
Figure AA shows my prototype of a cockpit. I did a screenshot of the simulator screen, cropped out the bottom part, and printed it. This was my template for the switch arrangements. I used switches I found at a surplus store. The whole structure can be made from plywood or MDF. I used a kind of ridged cardboard and covered it with black vinyl. It just depends on how realistic you want your cockpit to be.

To keep the software as versatile as possible, I set some limitations. For example, I don't have an auto-repeat. Sometimes it is not easy to create hardware, like a lever with a switch attached that generates just one pulse. If the switch is on the whole time, it will NOT cause more keystrokes to be sent. For the flight simulators, is it okay. For other games, the opposite is needed (like with a pinball machine.) If you hold the key on the keyboard down, the Flapper will stay extended.

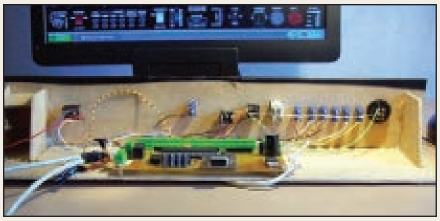
■ FIGURE AB. Detailed look at the switch selection.



■ FIGURE AC. I used a limit switch for the landing gear function.



■ FIGURE AD. Wiring details.



■ FIGURE AE. The serial connector.

The key for flaps up (in increments) is 'F6' and F7 for down (in increments). The respective code is therefore: '0B' for push and 'F0 0B' for release (F6). Enter those data into the fields for the inputs and download it to the PIC. Don't forget to save the data!

There is one limit at this time: If you have to send a 'Ctrl + A' or a combination of SHIFT or ALT codes, this will not work (not yet!). Generally, it is possible to change the setup within the simulation to accommodate this problem. Happy flying! **NV**

Sources

Here's a couple layouts for the keyboard codes:

www.beyondlogic.org/keyboard/scancode.gif

www.beyondlogic.org/keyboard/scancod1.gif

PARTS LIST

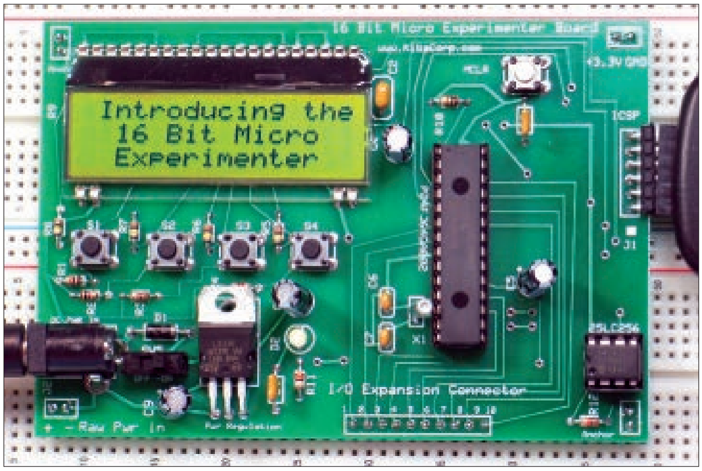
ITEM	DESCRIPTION
IC1	16F877 with software
IC2	24LC16B
IC3	MAX 232
VR1	L 7805 CV
D1	1N4148
D2	1N4001
Q1	Ceramic resonator 20 MHz
C1	100 nF
C2	10 µF/25V
C3	10 µF/25V
C4	10 µF/25V
C5	10 µF/25V
C6	10 µF/25V
C7	10 µF/25V
C8	100 nF
C9	100 nF
R1, R2, R3	4.7 KΩ
R4, R5	10 KΩ
Rn1, Rn2, Rn3	10x4.7 KΩ array (or eight single resistors 4.7 KΩ)
Rel 1	Relay R40-1102-5 (NTE)

One 40-pin socket
One 16-pin socket
One eight-pin socket
One nine-pin SUB-D female
Two triple terminals (three connections)
14 double terminals (two connections)
One keyboard extension cable

By Tom Kibalo

A 16-Bit Micro Experimenter for Solderless BREADBOARDS

Ready to move on from eight-bit to 16-bit microcontrollers? Well, you're in luck! In this and upcoming articles, we will be introducing you to a new solderless breadboard based on 16-bit technology — "the 16-bit Micro Experimenter" (or "Experimenter" for short). The Experimenter will be offered as a kit from *Nuts & Volts*. It comes with a CD-ROM that contains details on assembly, operation, as well as an assortment of ready-made applications. New applications will be posted at www.KibaCorp.com for free download. In this article, we will introduce you to the Experimenter, show some quick experiments that can be done "right-out-of-box," and show a really neat Christmas application that you can build for the holidays.



■ FIGURE 1. The 16-bit Micro Experimenter shown with the PICKIT2.

I know what you're thinking, this is cool, but do I need to learn a whole new set of tools to get started? Not at all! If you have been following the *Nuts & Volts* articles on embedded C programming and the PICKIT2, then a lot of what you've learned for those eight-bit developments extends very neatly into the 16-bit world.

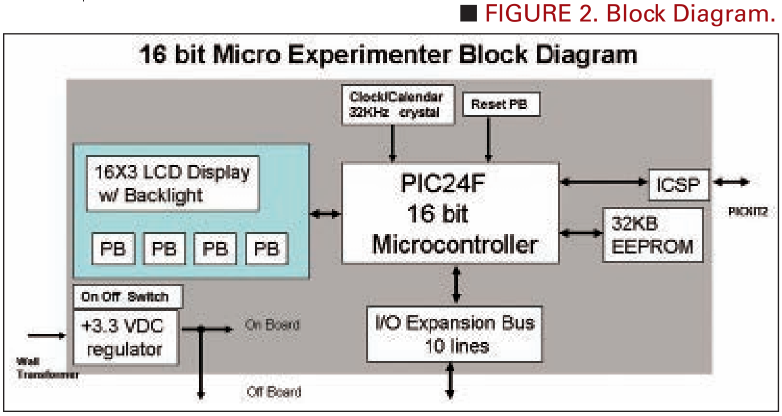
Overview of the Experimenter

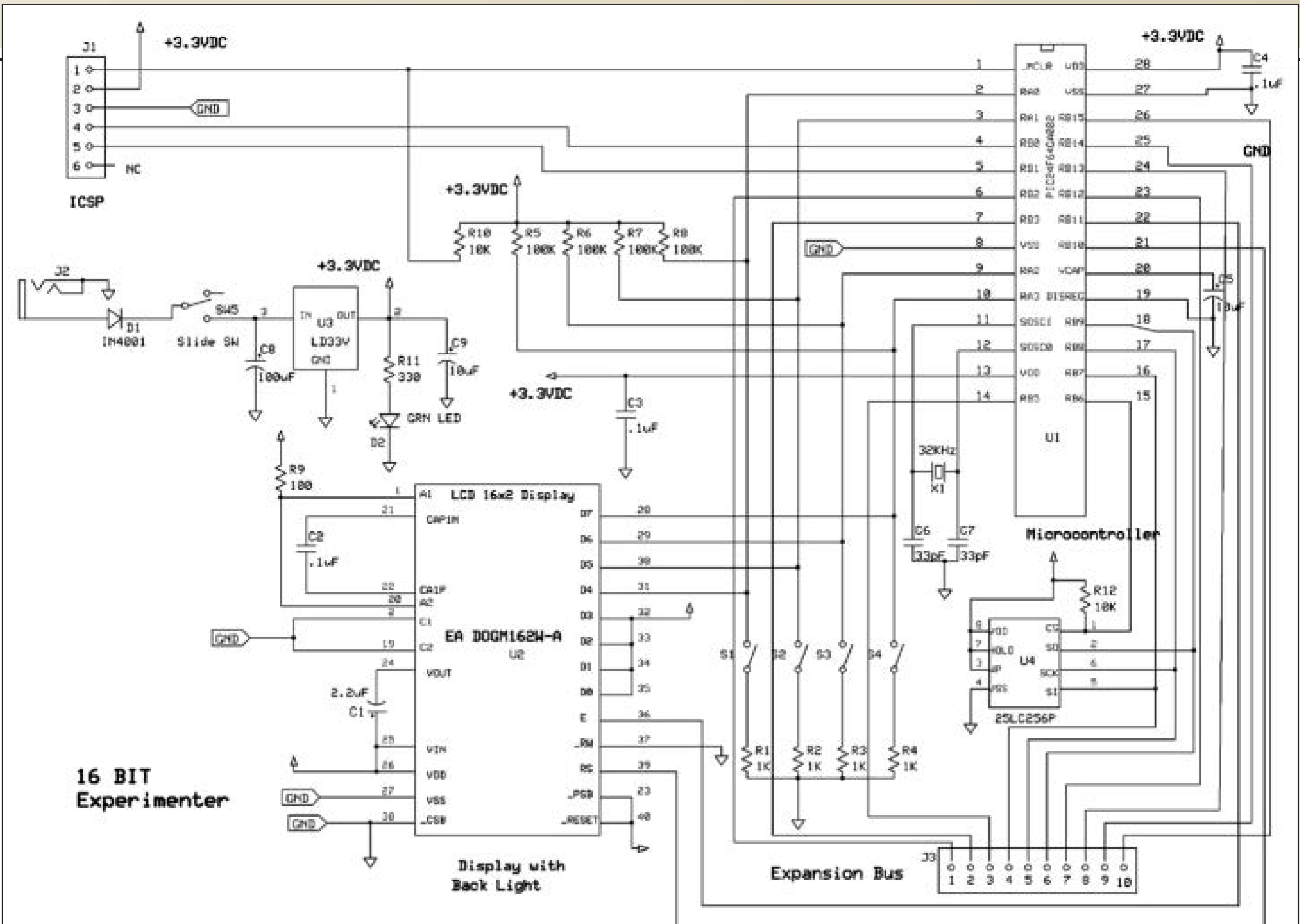
The Experimenter was born out of the need to use 16-bit machines, yet still stay in a solderless breadboard environment. For us hobbyists, solderless breadboarding is a great way to prototype and test ideas. Basically, you have fun without a lot of assembly. However, when I first started to breadboard 16-bit designs, I found myself adding a lot of I/O in the form of display, pushbuttons, and other supporting ICs. In the end, a significant part of the larger solderless breadboard reality was already occupied before I could even get started. The 16-bit Experimenter helped me get around all that. It is a complete microcontroller with user interface that plugs into the solderless breadboard. With the Experimenter, you not only have an LCD display, pushbuttons, and long term storage EEPROM, but also the Microchip ICSP interface for program and debug support on board (see **Figure 2**).

The Experimenter has its own regulated power source: and on/off switch that supplies power to the module from either a DC power source or wall transformer. This power source can also feed other solderless breadboard components. Finally, the Experimenter supports an I/O expansion bus that allows you to easily hook it up with other components you may need as part of your experiment. In short, the Experimenter captures all the basic support needs for using 16-bit microcontrollers on solderless breadboards.

The centerpiece is the PIC24F microcontroller. The

■ FIGURE 2. Block Diagram.





■ Experimenter Schematic 1.

PIC24F is the lowest cost, 16 MIPS (million instructions per second) microcontroller available from Microchip.

Companion to the PIC24F is a 32 KB serial EEPROM (25LC256) that allows for flexible non-volatile storage as required during program operation to store those necessary items for some applications like calibration data, password, or even miniature web page content.

The Experimenter is also equipped with a clock crystal to insure accurate time keeping with the PIC24F internal Real Time Clock Calendar peripheral (RTCC).

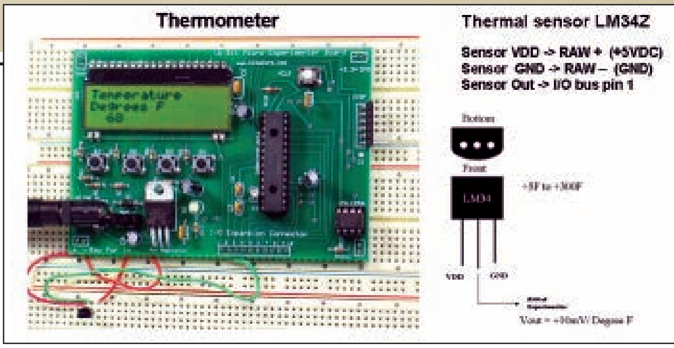
The PIC24F is a +3.3V part, as well as all the other components on the Experimenter. However, all inputs on the I/O expansion bus are +5V tolerant, and all the digital only I/O expansion bus outputs can be configured to be open drain (open ended CMOS outputs), as well. These outputs can be tied to external pullup resistors to +5V to achieve +5 volt levels. The whole scheme allows for easy transitions when interfacing with +5V logic families.

The Experimenter assembly is 4.25" x 3.3" and is recommended for use with larger solderless breadboard (3260 contact). Take a look at the **schematic** for the Experimenter.

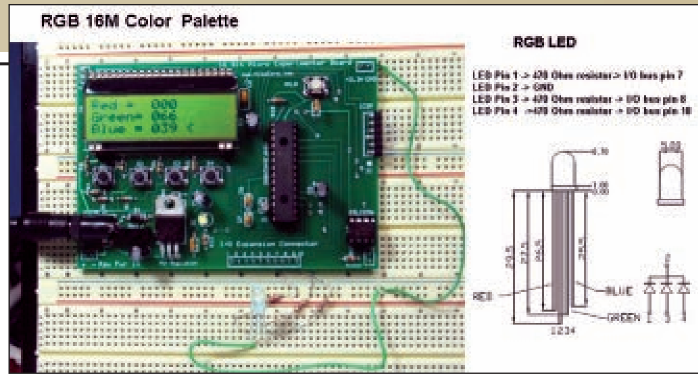
PART DESCRIPTION

C1 2.2 µF Mouser 647-UVZ1H2R2MDD
C2 .1 µF Mouser 581-AR211C104K4R
C3 .1 µF Mouser 581-AR211C104K4R
C4 .1 µF Mouser 581-AR211C104K4R
C5 10 µF Mouser 647-UVZ1J100MDD
C6 33 pF Mouser 80-C315C330J1G5CA
C7 33 pF Mouser 80-C315C330J1G5CA
C8 100 µF Mouser 647-UVZ1C101MDD
C9 10 µF Mouser 647-UVZ1J100MDD
D1 All Electronics IN4001
D2 All Electronics GREEN LED MLED-2
J1 Jameco six-pin 100 header right angle
J2 SparkFun DC power connector
J3 10-pin.100 header
JX1 Two-pin100 header power connector +3.3V
JX1 Two-pin100 header raw power out
JX2 Two-pin100 header anchor
JX3 Jameco two-pin100 header anchor
R1 1K Mouser 299-1K-RC
R2 1K Mouser 299-1K-RC
R3 1K Mouser 299-1K-RC
R4 1K Mouser 299-1K-RC
R5 100K Mouser 299-100K-RC
R6 100K Mouser 299-100K-RC
R7 100K Mouser 299-100K-RC
R8 100K Mouser 299-100K-RC
R9 100K Mouser 299-100K-RC
R10 10K Mouser 299-10K-RC
R11 330 Mouser 299-330-RC
R12 10K Mouser 299-10K-RC
S1 All Electronics Min tacile
S2 All Electronics Min tacile
S3 All Electronics Min tacile
S4 All Electronics Min tacile
S5 All Electronics Min tacile
SW5 Mouser Slide SW 506-MMS12
U1 Microchip Direct PIC24F64GA002
U2 Mouser Display EA DOGM162L-A
U3 SparkFun LD33V COM-00526
U4 Microchip Direct 25LC256P
X1 Jameco CY32.76
M1 Jameco DIP socket 28-pin 0.3"
M2 Jameco DIP socket eight-pin
EXp16 Board **www.KibaCorp.com**
RGB LED **www.sparkfun.com** triple output RGB LED sku: COM-00105
Ethernet Module SparkFun Ethernet Interface Board ENC28J60 sku: BOB-00765

www.mouser.com
www.allelectronics.com
www.jameco.com
www.sparkfun.com



■ FIGURE 3. Thermometer Demo.



■ FIGURE 4. RGB Demo.

Development Tools

The development tool set to use is Microchip's inexpensive Integrated Development Environment (MPLAB), the free student edition of their PIC24 C compiler, and the PICKIT 2 debugger and programmer kit. The links are:

- Free Microchip's MPLAB **www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en019469&part=SW007002**
- Free Microchip evaluation version C complier. **www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en535364**

The PICKIT2 kit is available from *Nuts & Volts* website.

I/O Expansion Bus

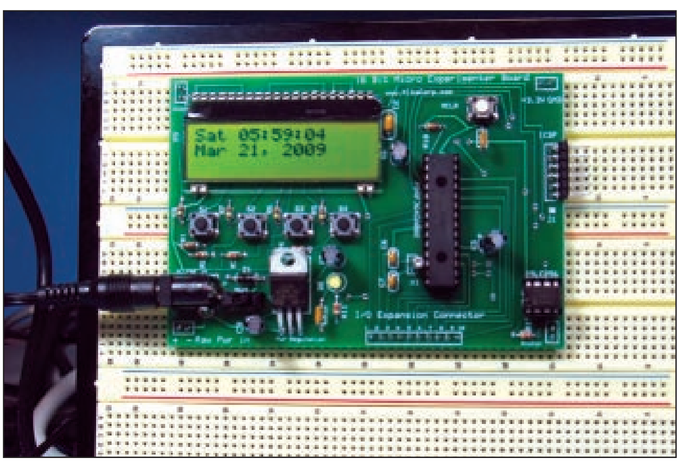
The Experimenter I/O bus is used to connect your breadboard hardware to the Experimenter module. There are a total of 10 pins available. Each pin is programmable and allows access to any of the internal peripherals with the PIC24F. More on this later.

The Experimenter in Operation

The Experimenter comes with a series of preprogrammed demos. The Experimenter introduces itself and its capabilities through a series of Flash screens on the LCD. There are a total of 11 screens; each lasts about four seconds, with the entire sequence continuously repeating itself. This is actually a good indication that the unit is up and working just after your assembly.

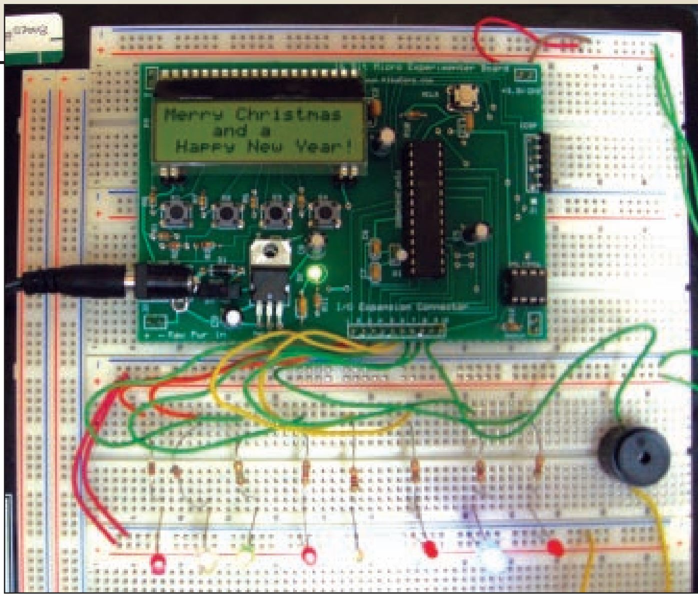
By pressing the S1, S2, and S3 pushbuttons you can select one of the three built-in demos to explore the Experimenter. Keep in mind that to run some of these experiments, you'll need to use some additional hardware. You can exit any demo and return to the flash displays any time by simply pressing S4.

■ FIGURE 5. Clock/Calendar Demo.



Button S1 Demo: A Thermometer

This demo configures pin 1 of the I/O expansion bus to be an analog input and then continuously digitizes it using the PIC24F internal 10-bit ADC. The results are displayed in degrees Fahrenheit. You'll need to connect an LM34Z sensor.

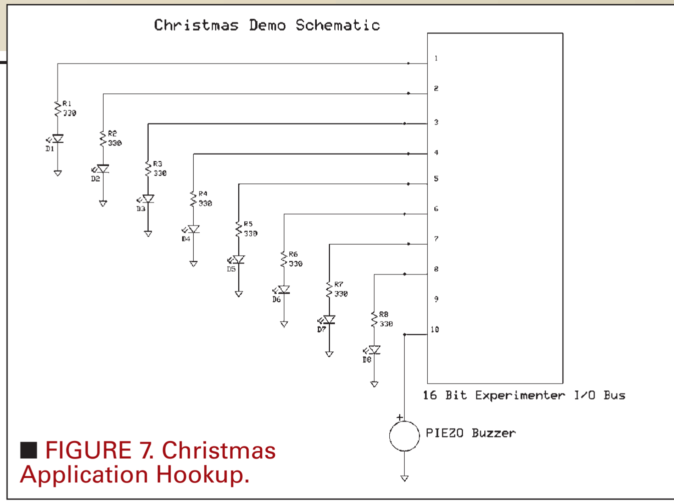


■ FIGURE 6. Christmas Application.

Use a raw input of +5 VDC to power the sensor. This can be done simply by applying power to the board through the RAW + and - inputs rather than using a wall transformer.

Button S2 Demo: An RGB Color Generator

This demo configures I/O expansion bus pins 7, 8, and



■ FIGURE 7. Christmas Application Hookup.

10 to be independent pulse generators (using the PIC24F output compare modules) to separately PWM each of the three RGB LEDS (red, green, and blue). Each PWM output has a setting from 0-255 which can be set via the LCD and pushbuttons so that you can get 255 x 255 x 255 or 16M different colors under this arrangement. You need to connect an RGB LED as indicated, using 470 ohm resistors in series with each LED anode and a common cathode to ground. I got my RGB LEDs from SparkFun. To exit and go back to the flash screens, simply press S4.

Button S3 Demo: A Clock Calendar

This demo enters a mode where pushbuttons assume clock setting and control operations for an internal 100 year, real time clock calendar with an alarm. User options are: change mode from clock display to clock setting and enter clock changes; stay in clock mode to simply display clock; or exit clock mode back to flash screens. Designated button functions are as follows:

- Button S1: Toggle between clock run mode and clock setting mode.
- Button S2: If in clock setting mode, increment current data field.
- Button S3: If in clock setting mode, decrement current data field.
- Button S4: Advance to next allowable data field if in clock setting mode or if pressed in clock run mode, exit to flash screens.

A Holiday Application

To round things off, we put together a holiday light and sound application using the Experimenter. It powers up wishing you a “Merry

Christmas and a Happy New Year" on the LCD screen while randomly flashing eight LEDs connected to the I/O expansion port (see **Figure 6**). I used a variety of colored LEDS to make it more interesting and changed the series resistor associated with a particular LED as needed to make it brighter (anything from 1K to 330 ohms). I then hooked up a +3.3V piezo beeper (All Electronics #SBZ-203) to I/O bus expansion pin 10 and configured that pin as a PIC24F PWM generator for sound. When the user depresses SW1, the Experimenter plays a stanza of Jingle Bells while showing lyrics on the LCD. When finished it returns to the "Merry Christmas" display.

Programming the Experimenter Holiday Application

The Demo application code for this project is downloadable from the *Nuts & Volts* website (**www.nutsvolts.com**). Make sure to install all the tools beforehand. Please download, unzip, and place the project folder "Christmas" and put these in a convenient location on your computer. Now connect the PICKIT2 to the USB on your computer and the other end to the ICSP on the Experimenter. Switch on power to the Experimenter. Open the folder containing the application code and double-click the project file Christmas.mcp. You should see the MPLAB GUI with the demo project directory visible; C code for the Main function open; and the output window should display the PICKIT2 ready, PIC24FJ64GA002 found, and show that target power is applied.

On the IDE toolbar, click the Build button, and watch the IDE and PIC24 C Compiler compile the program. The output window should indicate no compile error. Use the Program option pulldown list and select "program". The PICKIT2 will then actively program the PIC24F Flash on your breadboard through the ICSP. At the completion of this, your Experimenter should automatically come up with the Christmas Application. You can now either remove the PICKIT2 from the ICSP or leave it connected. The Experimenter will now work independently on each power-up cycle.

Where Do We Go From Here?

Congratulations! We now have a 16-bit Micro Experimenter. We have essentially completed a development system. Upcoming articles will lead us through other fun applications. Happy Holidays and Happy 16-bit solderless breadboarding! **NV**

A full parts kit with PCB and pre-programmed PIC24F with demo is available through the *Nuts & Volts* webstore at http://store.nutsvolts.com.

Experiments with Alternative Energy

Part 5 - Experimenting with the "Double Wide" Sun Tracker

By John Gavlik, WA6ZOK

Last time, I showed you how to build a Double Wide Sun Tracker, but I didn't have room to go into a lot of the important details surrounding its operation and how to do more interesting experiments with it. That's what this month's article is all about. In it, I'll show you how to optimize the Sun Tracker by fine-tuning the mechanical, electrical, and firmware elements that can make for better, more customized operation. Plus, I'll show you how to do more advanced data logging with it. All in all, you should be able to take what you've learned from these five articles on solar energy and have a better understanding of how we can gather more of the sun's energy through photovoltaic solar panels along with sun trackers.

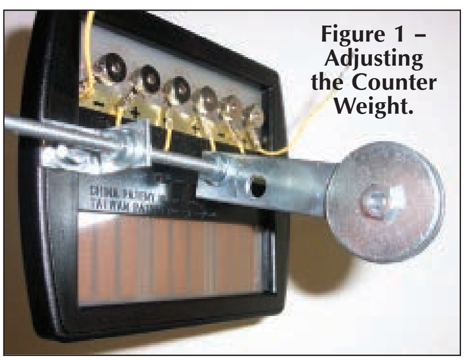


Figure 1 – Adjusting the Counter Weight.

Sun Tracker Optimization Techniques

The Sun Tracker's operation can be optimized in three basic ways:

- Mechanically
- Electrically
- Programmatically

Rather than speak in general terms about how to best set up and use the Sun Tracker, the bulk of this article will address the details surrounding these topics. Let's start with a simple mechanical adjustment and go from there.

Achieving Good Balance

An important mechanical consideration is properly balancing the cantilevered solar panels with counter weights. Because our particular solar panels have threaded screw terminals for attaching wires, this added weight — however small — must be compensated for by angling the counter weight bracket properly. **Figure 1** shows the general angle for obtaining the correct balance which is pointing down. You can experiment with adjusting the counter weights by first removing the threaded rod from the mounting bracket and disconnecting any wires going to the test bed. Be sure to keep the wires attached to the screw terminals.

While holding the opposite ends of the threaded rod in each hand, give the panels a gentle spin. If the panels spin smoothly over and over without any wobble and come to rest at any angle, they are balanced. However, if they wobble, always come to rest at the same orientation, and seem like they take a lot of force to rotate, move the counter balance weights "slightly" one way or the other until a good balance is achieved. Then, replace the threaded rod assembly with the solar panels on the mounting bracket and reattach the wires to the test bed. Proper balance will keep the motor's East-West movements in line with good tracking.

Adding a Load to the Solar Panels

One important feature of the Sun Tracker's electrical design is the ability to add a load to the solar panels without the geared motor interfering with periodic current and voltage drains when activated. The geared motor is driven by the 1.2 volt NiMH battery through the H-bridge circuit, and it has its own one ohm sense resistor to measure its current when activated (**Figure 2**).

A separate one ohm sense resistor is also provided to measure current into the load from the solar panels so that you can make voltage, current, and power measurements for

experimental purposes without any electrical distractions from the motor. Since the solar panels can be wired in any number of series and parallel configurations, there are multiple ways in which you can conduct your experiments.

To assist you in your experimental efforts, refer to **www.learnonline.com** → Experimenter Kits → BS2 or 28X2 → Solar Panels in Series and Parallel. This will show you how to best configure solar panels in series and parallel, and the addition of the sun tracking feature should make these experiments even more interesting.

Effectively Tracking the Sun

The voltage output of the solar panels themselves — regardless of how they are wired or loaded — can be used to sense and maintain adequate sun tracking; we don't need a special light sensor. There is, however, one way to improve the tracking ability by adding a hood around the solar panels to better channel the light. This will help to detect the sun's position by creating steep "channels" to focus the light onto the panels. This will help in tracking as well as evenly generating more reflected light on the panels themselves (see the sidebar on *Simulating Cloud Reflections*). By designing a hood that uses highly reflective materials (like "smooth, reflective" aluminum foil), your chances for improving the tracking and light gathering ability improve dramatically.

I designed the Sun Tracker to work both indoors and outdoors — outdoors being best, of course. The Parallax BS2 on the BOE and Homework boards can be powered by a nine-volt battery, so working outside without AC power is certainly doable. The PICAXE setup is a different situation since it gets its working voltage from the USB connection to a computer. So, maybe a laptop is in order for this setup. Either way, the idea is to be clear of obstructions so that continuous sun tracking and data logging can take place in a natural setting.

Firmware Adjustments

In designing the firmware, I purposely used a number of constants that can be adjusted to configure your Sun Tracker in ways to suit your individual requirements. Some of the constants are independent while others are interdependent on other constants, especially those that involve timing. To get a feel for how these constants work, refer to the Sun Tracker code at **www.learnonline.com** → Experimenter Kits → BS2 → Parallax_Sun_Tracker_Exp.bs2 or **www.learnonline.com** → Experimenter Kits → 28X2 → Picaxe_Sun_Tracker.bas. Use the code as a reference for the following discussions.

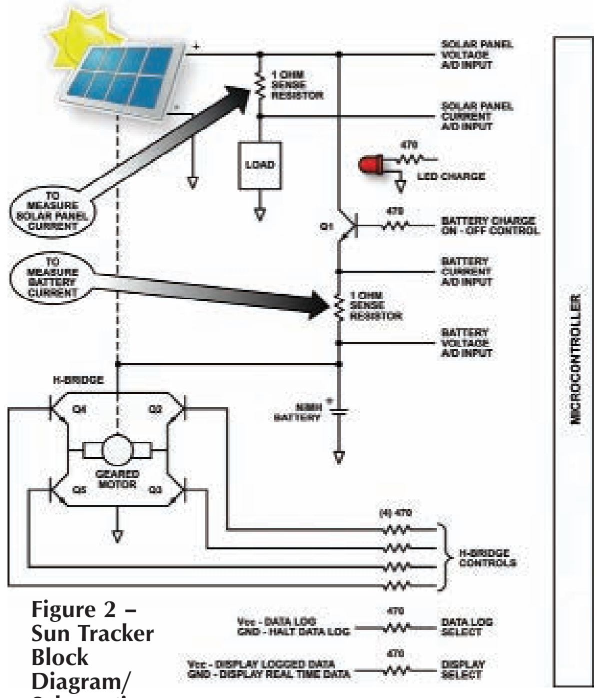


Figure 2 – Sun Tracker Block Diagram/ Schematic.

Adjusting the Battery Charging Constants

There are three constants that affect the "On Demand" battery charging part of the firmware:

- fullChargeVolts
- fullDischargeVolts
- minEnergy

The fullChargeVolts constant defines the voltage (in millivolts) where the battery is at an acceptable level just after charging. Right now, this value is set at 1.2 volts or 1,200 millivolts, but you can change it to anything you like within reason. Remember that our NiMH battery operates at 1.2 volts (or slightly higher), so this is why I chose this value. The equivalent constant, fullDischargeVolts, is the level at which the battery requires charging. I have this set at 900 millivolts since our H-bridge circuit needs at least the full 1.2 volt voltage of the battery to operate; I chose this voltage to be high enough to begin recharging shortly after the battery voltage begins its rapid decline during the beginning of its discharge cycle, but well enough below the

```
'-------------------------------------------------
'   Main Routine
'-------------------------------------------------
Main:
  PAUSE 250                        'adjust this delay so the time through the Main
                                   'loop is approximately 1 second
Sun_Tracker:
  IF  (searchTrack = 0) THEN       'decide on how to track the sun
    GOSUB Sun_Search               'just starting out at the beginning of the day or
  ELSE
    GOSUB Sun_Track                'after finding out where the sun is and tracking it
  ENDIF

Battery_Charger:
  IF (charging = 0) THEN           'decide whether or not to charge battery if
    GOSUB Test_Battery_Voltage     'battery voltage is above minimum or
  ELSE
    GOSUB Charge_Battery           'if it needs charging
  ENDIF                            'LED will remain ON for entire charging cycle

Data_Logging:                      'Log Data or Not (P11)
  IF (IN11 = 0) THEN               'if P11 = 0 (ground) disable data logging
    GOSUB Clear_Logged_Data        'and erase logged memory
  ELSE                             'LED will NOT flash as long as P11 = 0
    GOSUB Log_Data                 'else, log data every 2 minutes
  ENDIF                            'LED will flash once every time thru Main
                                   'And flash longer when event is logged
                                   'LED will flash 4 times when data log memory is
Display_Data:
  IF (IN15 = 0) THEN               'Display Real Time or Logged Data (P15)
    GOSUB Plot_Real_Time_Data      'display real time solar data when P15 = 0
  ELSE
    GOSUB Plot_Logged_Data         'display logged solar data when P15 = 1
  ENDIF


GOTO Main
```

Figure 3 – Parallax BS2 Firmware Main Loop.

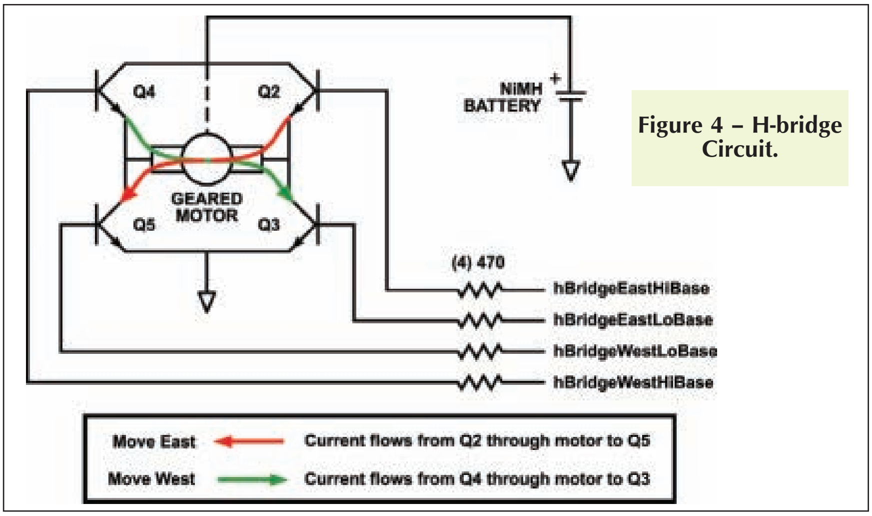


Figure 4 – H-bridge Circuit.

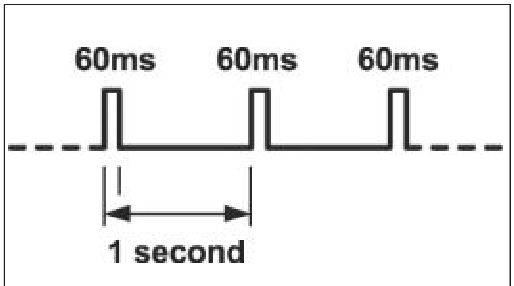


Figure 5 – MotorOn PWM Pulsing (not to scale).

fullChargeVolts so as not to cause undo toggling between charging and discharging (more about the H-bridge circuit coming up).

The other battery charging constant is called minEnergy. This is the accumulation of current — measured on a one minute basis — that is necessary to adequately charge the battery to a prescribed level. I have this set at 1/20 C for my 2,450 mAh batter; it should be adjusted to your particular battery's capacity for best results. Refer to Part 3 for details on how to compute this value and what it means.

Timing is Everything...

And so it is for our Sun Tracking firmware — as in adjusting the time through the Main Loop which is currently set at one second. All the major firmware subroutines — sun tracking, battery charging, data logging, and data output to the computer — are based around this one second Main Loop timing. Activities within these primary subroutines contribute to most of the one second time delay. However, I put a PAUSE statement at the top of the Main Loop to adjust the total time to about a second (**Figure 3**).

You can change this PAUSE value to fine-tune the speed through the Main Loop, but you will be affecting all the other time-related functions as well, so be careful with what you do. Just adjust it to make the one second transition through the Main Loop as accurate as possible considering all the time used for flashing the LED, averaging voltages, and transmitting data along with the other firmware delays. Being close to a second is good enough in this case.

If you experience hesitant delays through the Main Loop timing, it's probably due to the Get_Average_Voltages routine. In it, the firmware averages the solar panels and battery voltages along with the voltage drops across individual one ohm sense resistors for each of these two voltage sources. The firmware routine requires that the voltage drop across the one ohm sense resistors always be less than the solar panel or battery voltage.

From time to time — because of sampling and voltage averaging variations in this subroutine — this required voltage condition may not always occur. When this happens, the code loops back to take another set of voltage samples until the one ohm voltage drops are less than the source voltages they're attached to. This is what adds to the time through the Main Loop. You can see this "hiccup" if you are data logging and see the LED flash rate interrupted from time to time. It's nothing to be concerned about; just be aware of why it's happening.

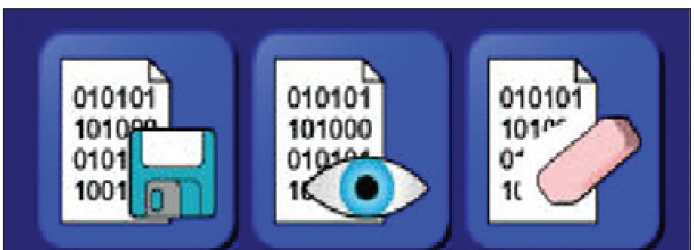


Figure 6 — REEL Power Software Data Logging Icons.

H-Bridge Operation

The H-bridge circuit controls the geared motor operation that moves the solar panels. Due to lack of space, I didn't have a chance to tell you how it works last time, but since it's an integral part of the Sun Tracker circuitry I'll do it now. The H-bridge circuitry consists of four NPN transistors and four 470 ohm base resistors that, together, control the back and forth motion of the motor (**Figure 4**). It works like this: The firmware uses four microcontroller ports with the following labels to control the ON-OFF states of the four NPN transistors:

- hBridgeEastHiBase controls Q2
- hBridgeEastLoBase controls Q3
- hBridgeWestHiBase controls Q4
- hBridgeWestLoBase controls Q5

In order for the H-bridge to work, two of the transistors must be turned ON and the other two turned OFF. This condition directs current from the battery through the two ON transistors and through the motor in order for it to move in one of two directions. For example, to move the motor East, transistors Q2 and Q5

are turned ON while Q3 and Q4 remain OFF. This allows current to flow from the battery through Q2, through the motor, and then through Q5 to ground. This is done by the micro setting the transistor base controls as follows:

- hBridgeEastHiBase Q2 - High (1)
- hBridgeEastLoBase Q3 - Low (0)
- hBridgeWestHiBase Q4 - Low (0)
- hBridgeWestLoBase Q5 - High (1)

To move the motor West, we simply reverse the direction of current flow by turning Q3 and Q4 ON while keeping Q2 and Q5 OFF as follows:

- hBridgeEastHiBase Q2 - Low (0)
- hBridgeEastLoBase Q3 - High (1)
- hBridgeWestHiBase Q4 - High (1)
- hBridgeWestLoBase Q5 - Low (0)

To halt the motion of the motor, all transistors are turned OFF (logical 0 on the base resistors). Each transistor drops about 0.6 volts when ON (1.2 volts total with two transistors ON with current flowing through the motor), so you can see that our motor hardly needs any voltage to rotate given that the battery voltage is nominally 1.2 volts, as well. That's why I chose this particular motor for its low voltage/low current capabilities along with the integrated gearing that allows it to move our relatively heavy panels (see the sidebar on the internal view of the geared motor).

If you don't see how the H-bridge works at first, look at **Figure 4** again and it will begin to make sense. It took me a couple of mental tries the first time I came across this circuit, so if you're new to this design give it another look. You can use it with modifications like substituting MOSFETs to replace the regular transistors in high-current, high-voltage motor controller designs. So, it's worth understanding.

Using PWM to Move the Motor

If I simply kept the transistors in their ON states all the way through the Main Loop until the solar panel's voltage was retested a second later, the motor would spin too fast twisting the solar panel's wires around the threaded rod in the process. To slow it down, I "pulse" the motor in a modified PWM (Pulse Width Modulation) fashion. The firmware variable motorOn controls the duration of the motor's ON time so that it's only allowed to move incrementally East or West (**Figure 5**). You are free to change the motorOn time duration; however, too little time may not be enough to overcome the starting inertia of the mechanical solar panel load to get it moving. Too much time may move the solar panels too far, so experiment with it to see how it works; then decide on a reasonable value to move the

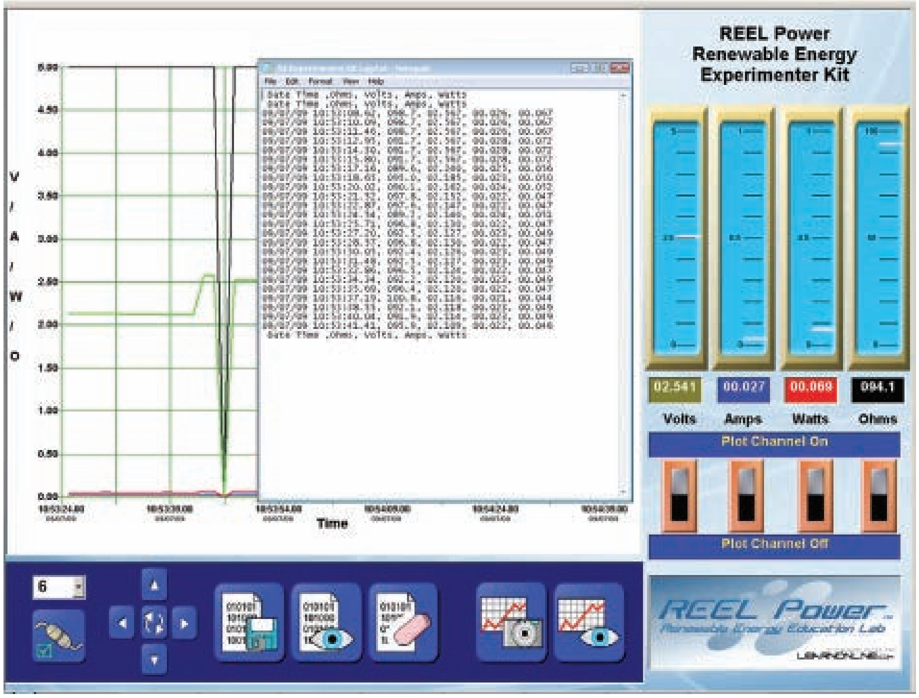


Figure 7 – Logged Data Overlaid on Data Plot.

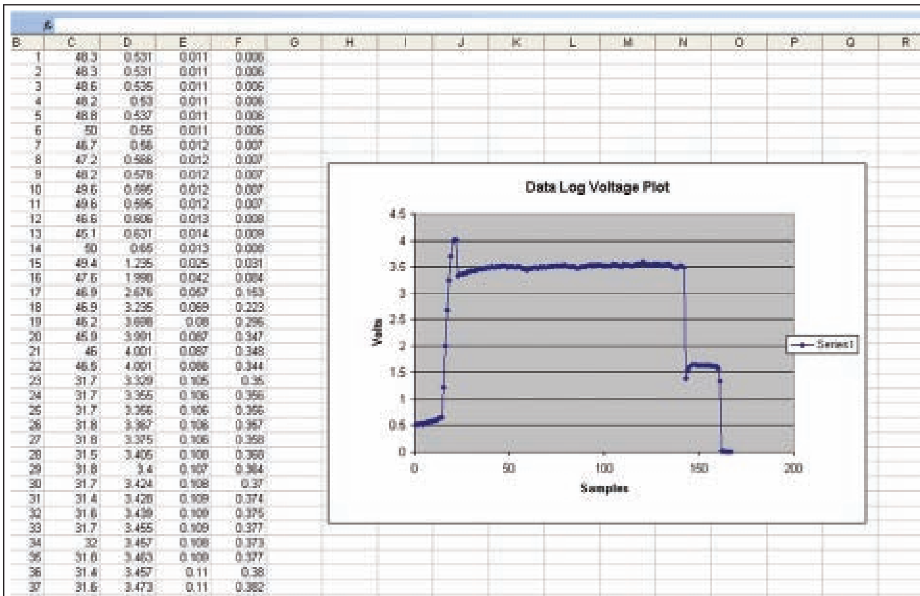


Figure 8 — Logged Data Plotted in Excel.

Geared Motor

A geared motor uses two pinion gears and two spur gears to reduce the speed of the DC motor and provide additional mechanical advantage through the output shaft for moving the solar panels. The photo shows the inner-workings of this mechanism.

motor for best tracking.

Advanced Data Logging

Now that we've given the Sun Tracker a good tune-up, it's time to address how to best use it effectively. By this, I mean applying the data logging features built into the REEL Power software program. In addition to the data logging capability built into the Sun Tracker firmware, the REEL Power software can also be used to archive the day-long logged data from the micro to a text file that can then be ported to a spreadsheet program like Excel in order to plot and compare logged data from different days of experimentation.

Here's how it works. The REEL Power software has three data logging controls located at the bottom of the screen (**Figure 6**). Data logging with the software is defined as capturing each four-byte voltage and current data packet sent by the BS2 or 28X2 and saving it in a text file. In doing so, the data packet is "time tagged" with the current date and time (NOT the date and time when the data was actually recorded, but the current date and time when the data packet is received by the computer from the BS2 or 28X2). From the received solar panel voltage and current data, the REEL Power software also computes the power and load resistance values, and the result is a data record that looks like this:

Date	**Time**	**Ohms**
09/07/09	10:53:08.62,	098.7,
Volts	**Amps**	**Watts**
02.567,	00.026,	00.067

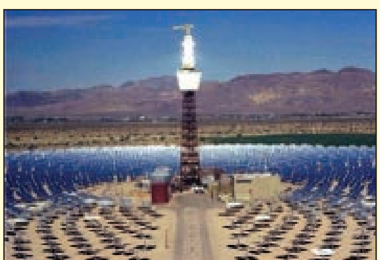
Again, the REEL Power software does this for each data packet that it receives. To start data logging with the REEL Power software, click (once) on the left-most icon (the one with the floppy disk). This starts the recording process. Clicking on this icon again will stop the recording. So remember, click once to start and once to stop data logging (like a push-on, push-off switch). The icon will change from dark to a lighter shade when data logging is activated.

You can view the accumulated logged data by clicking on the middle icon (the one with the eye). A screen similar to **Figure 7** will pop up to show what's been recorded so far. Repeated clicking on this icon will bring up more accumulated data. However, each time a new instance is generated the task bar at the bottom of the computer screen will begin to fill up, so be prudent in your clicking. Finally, you can erase all the currently logged data by clicking on the right-most icon (the one with the eraser). This clears all the currently accumulated logged data, but it doesn't stop the data logging process by itself; it only clears the logged data thus far. To clear the logged data completely and stop the data logging, you must click the left-most icon to halt the logging process first. Then, click the erase icon to clear everything once and for all. The best thing to do is experiment with these icons to get familiar with them using any sort of Sun Tracker data coming into the software. Then you'll be ready for our next exercise.

Transferring Logged Data from the Sun Tracker to the REEL Power Software

When you have logged some

Dual-Axis Trackers



Dual-Axis Heliostat System.

Our Sun Tracker is a single-axis type meaning it moves only East and West, and doesn't have any automatic adjustments for moving up and down to follow the seasonal altitude changes of the sun. Dual-axis trackers — meaning vertical (altitude) and horizontal (azimuth) movement combined — can and are used for flat PV panels. However, their main applications these days are in concentrator and heliostat systems where precise sun tracking on a year-round basis is a must.

A concentrator system accurately focuses the sun on small PV modules using Fresnel lenses or a parabolic dish. A primary advantage of this type of system is that less physical area is dedicated to flat solar panels. The drawback is the high cost of the dual-axis system tracking the dish and the necessary cooling required to maintain the PV modules at the optimum operating temperature.

A heliostat is really a set of curved mirrors that are focused by individual tracking mechanisms to a central point in order to generate concentrated heat at that point. Constant and precise sun tracking is necessary to keep the mirrors aimed at their target. The image at the left shows a heliostat "farm" that concentrates the sun's heat on a central tower where molten "salt" is circulated to heat water to create steam in order to produce electricity by conventional steam generators. The salt doesn't lose its heat during the night hours which allows the installation to generate electricity 24 hours a day. *Images courtesy of Wikipedia.*

Dual-Axis Sterling System.

data with the Sun Tracker, the best way to transfer it into the REEL Power software is to first start at the beginning of the logged data sequence. You can do this by depressing the reset button on the BOE or Homework board, or by cycling power on either the Parallax or PICAXE setup. At the same time, click the data log icon; this starts a new file recording sequence. The data packets from the Sun Tracker are now being saved to a text file on your PC at the same time they appear on the computer monitor.

When you want to stop gathering data from the Sun Tracker, click on the data log icon again; this stops the REEL Power software from logging any more incoming data packets. The logged data is now in a text file with the label "RE Experimenter Kit Log.txt". You can find this file on your hard disk under the Documents → REEL Power folder. Rename the file to something like SunTracker001.txt since the RE Experimenter Kit Log.txt file will be overwritten by future REEL Power software data logging actions.

Transferring the Renamed Data Log Text File to Excel

Once the data is in the renamed text file, transferring it to Excel is the next step towards graphing it and comparing data from previous sessions to the new data. The procedures to do this are a bit too involved to be covered here, so you can find them at **www.learnonline.com** → Experimenter Kits → BS2 or 28X2 → Experiments with the Sun Tracker. You can view an example of what can be done in **Figure 8**. The point of this exercise is to learn to use the Excel spreadsheet program in a new way for this application and, also, to create a means to use the Sun Tracker's data logging feature over many days, weeks, and months for long-term experimentation and data comparison.

Summary

This time, you learned the details of how the Sun Tracker works and how to expand its data logging capabilities. You should now be able to use the Sun Tracker in ways that will enhance your understanding of solar panel theory and technology.

With this article, we leave solar for a while and resume our study of alternative energy with my first article on wind generated power. Next time, we'll build a three-Phase AC Wind Turbine and interface it to the BS2 and 28X2 processors to measure voltage, current, power, and RPM. I'll also go into some wind turbine theory to help you understand how things work.

Like the Sun Tracker, the three-Phase AC Wind Turbine is an equally neat project that should teach you a great deal about wind turbine design and technology. So, until next time, conserve energy and "stay green." **NV**

(Image by Kipp & Zonen.)

Pyranometer

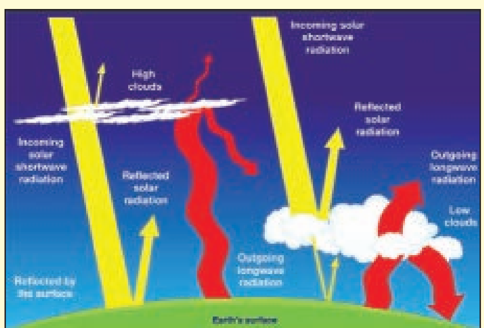
A pyranometer is an instrument used to measure the broadband solar irradiance generally in watts per square meter from a field of view of 180 degrees. In effect, a pyranometer indicates how much of the sun's energy is being deposited at the place where it's mounted at any given time. Sunlight enters the clear hemisphere where it is detected by a highly calibrated light sensor. It looks like a flying saucer, and many commercial and educational solar installations use it to compare the output efficiencies of their PV systems to what the sun is actually delivering at any given moment. A general rule for the sun's output is 1,000 watts per square meter at high noon on a clear day.

Simulating Cloud Reflections

Paper Reflections.

Clouds can both absorb sunlight, as well as reflect it. As seen in this NASA image, sunlight can bounce off the Earth's surface, then reflect off the bottom of clouds back to Earth. If a solar panel is receiving sunlight, it can get an extra measure of it from the bounced light.

To simulate cloud reflections, use a regular sheet of white paper or a mirror, and put it near the solar panels while the sun is shining on them. Hold it so that it reflects a portion of the sunlight back onto the solar panels. Then notice the voltage reading which should show an increase. This is what cloud reflections can do to increase the power and energy outputs of the solar panels.



Cloud Reflections.

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The Linux operating system also includes over 150 standard Linux/Unix system utilities including ftp, tftp, telnet, and vi. Also included in the development kit is a bootable Ubuntu CD-ROM preconfigured with development tools to support the OmniEP. Development kits with LCD, pushbutton front panel, and enclosure start at $299.

For more information, contact:
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www.jkmicro.com

BREADBOARD FOR SUN SPOT SYSTEM

A new accessory available from Circuit Monkey is a breadboard for the Sun SPOT System. The Sun SPOT system is based on the open source version of a revision C board found at **http://spot-breakout.dev.java.net**. This board plugs into the Sun SPOT and all of the signals from the 20-pin SPOT connector are brought out to female headers. These are ready to connect to the mini breadboard in the center. Board dimensions are 6 cm x 6 cm (2-3/8 x 2-3/8 inch). There are easy to use probe hook pads at the perimeter.

For more information, contact:
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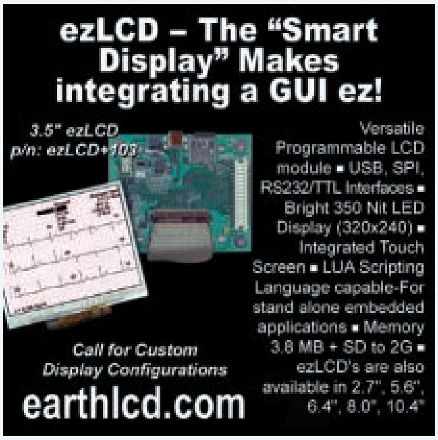
SHOWCASE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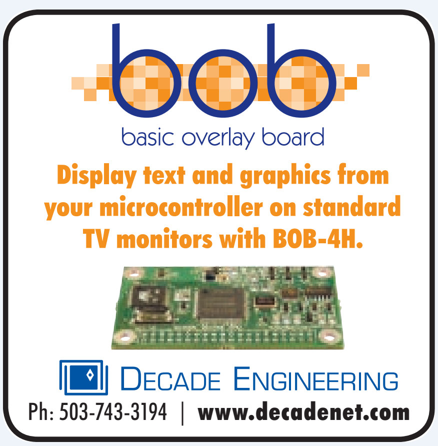
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THE DESIGN CYCLE

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■ BY FRED EADY

FIND THE HID-DEN VIRTUES OF USB

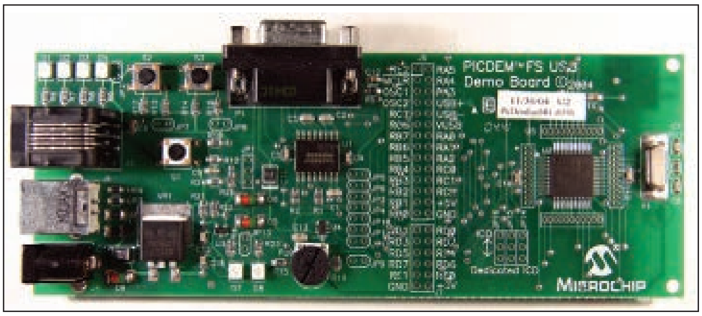
While we were extolling the virtues of USB as an RS-232 killer, we were totally ignoring one of USB's greatest strengths: the HID class. HID is USB-ese for Human Interface Device and is generally associated with mice, joysticks, and keyboards. However, did you know that HID class devices can also be designed to carry and transfer data? Guys and gals like us tend to steer away from HID programming tasks that carry data as cargo as we are normally required to take on the task of writing both the microcontroller and PC-side applications. The folks at Trace Systems (particularly Dr. Bob) and the USB wizards at Microchip realize this and have been working very hard to ease our programming pain.

In this installment of Design Cycle, we're going to do some HID programming beginning with the venerable Microchip PIC18F4550. Once we have the hang of HID programming with the eight-bit 4550, we'll break this camp and pitch our HID tent on a 16-bit platform — the PIC24FJ256GB110. Meanwhile, you may be wondering why you want to do this.

WHY HID??

If you're running one of today's standard PC operating systems, HID class devices are always welcome as Bill's Windows, Linus's Linux, and Steve's MAC animals natively support HID class devices. The key advantage of using USB HID class devices is that they don't require the installation of a special device driver. The secondary advantage of a HID class device is that it is capable of bouncing bytes around at 64,000 bytes per second. This figure is derived from the way a HID class device transfers data. HID class devices use two data transfer methods: Interrupt and Control. The maximum interrupt transfer rate of a full speed HID class device is specified as 64 bytes per millisecond. By the way, *interrupt* in the USB HID sense is not the same stop-what-I'm-doing-and-service-the-interrupt *interrupt* process a microcontroller employs. A USB HID device queues Interrupt request data until it is polled by the host. Control transfers are reserved primarily for command and status operations.

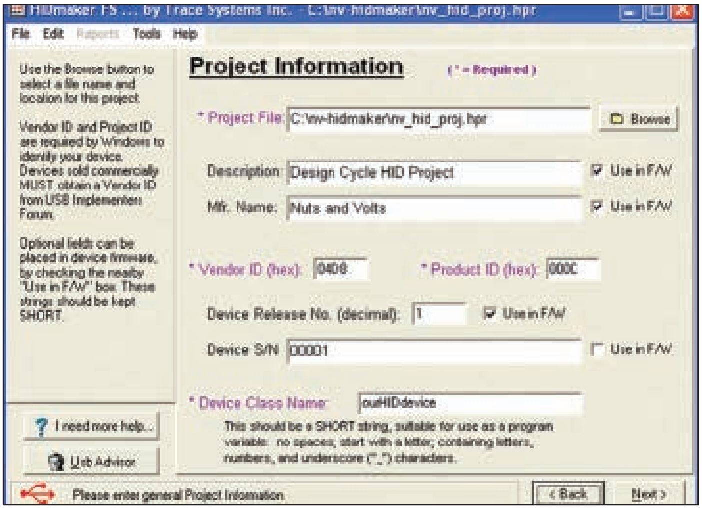
■ PHOTO 1. I like simple. There's nothing complicated at all about this circuitry and it's fully supported by the latest version of the MCHPFSUSB Framework.



The USB HID class is able to dodge specialized driver installations by clever and detailed implementation of descriptors. A descriptor is nothing more than a standardized numeric table that is used by the host PC to determine what the HID peripheral device is capable of and how to transfer the data between itself said device. Not only are the HID class data properties completely defined to the host PC, the HID class device is also described in detail to the host, as well. The USB specification and the HID descriptors insure that everything in a HID data transfer has already been defined on the host and peripheral sides of the USB equation. Since nothing HID is left to question, there is no need to support it with an additional operating system driver.

The data in a HID data transfer is packaged into what is called a Report. A Report is nothing more than a fancy name for a group of preformatted data bit fields. Data elements within the bit fields can range from one to 32 bits. HID Report elements are predefined and formatted in a Report Descriptor which gets transferred to the host PC during enumeration (yet another way HID class devices do an end around on specialized driver installation). In a HID environment, after the enumeration and configuration processes are complete there's nothing the host doesn't know about the data or the HID device.

So, it appears that if we can figure out how to assemble the HID descriptors correctly and accurately



■ SCREENSHOT 1. The VID (Vendor ID) and PID (Product ID) are borrowed from Microchip. Otherwise, I selected names and descriptions that we can easily pick out of the HIDmaker FS-generated descriptors.

interpret the Reports, we should be able to utilize the services offered to us by the HID device class to transfer meaningful application data between a HID peripheral device and a host. There are many tools at our disposal to assist in successfully implementing a HID class data device and the associated PC program. We will put two of them to work for us. Trace Systems offers a commercial program called HIDmaker FS which we will use to produce descriptors and code templates for both the device and the PC. On the manufacturer's side, Microchip provides a library of USB routines called the MCHPFSUSB Framework. This MCHPFSUSB Framework is part of their Applications Libraries, which are a free download from their website. The bottom line is that if the USB specification is followed, Dr. Bob's USB and Microchip's USB are the same USB, and will perform in an identical manner no matter whose descriptors we choose to stuff into our HID class device.

GO WITH WHAT YOU KNOW

Even today, the application-proven USB PIC18F4550 can be found on the front end of many a development board and USB-challenged microcontroller. You'll also find eight-bit PIC's performing the role of bootloader/debugger for more capable devices such as the 32-bit PIC32MX microcontrollers (check out my article on the Digilent Cerebot 32MX4 in the Dec '09 *SERVO*). However, our goal is to find some HIDden firmware treasure, not to design USB hardware. So, rather than design and build yet another PIC circuit, we'll feed our HID device firmware to a known-good platform: the PICDEM FS USB Demo Board. The PICDEM under the camera in **Photo 1** is a pure no-frills implementation. The PIC18F4550's I/O pins are all terminated on dual-row 0.1 inch header pads which are coupled to their respective trio of on-board pushbutton switches and quartet of LEDs. The PICDEM board can be powered from the USB portal or via an external power source. A potentiometer connected to the PIC's analog-to-digital converter, a TC77 temperature sensor, and a regulation RS-232 interface round out the demo board's main features. Now that we have a solid HID-capable hardware suite under us, let's turn our attention to the HID firmware.

The MCHPFSUSB Framework is actually a USB stack that conforms to the rules set forth in the USB 2.0 Specification. In the June '09 installment of Design Cycle, we used this MCHPFSUSB Framework to generate an RS-232-to-USB converter with Microchip's low pin count USB development kit. Before we're done, we'll use the MCHPFSUSB Framework to help us assemble a data-carrying HID application. The PIC18F4550 work will be relatively easy as the Framework includes a working PICDEM FS USB Demo Board HID demonstration application. While we're on easy street, let's drop in on Dr. Bob at Trace Systems and generate some HID code.

DESCRIPTION OF A DESCRIPTOR

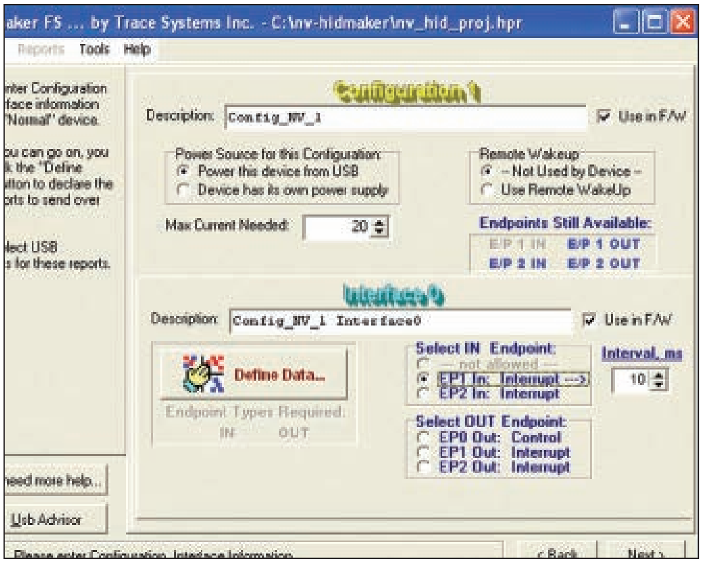
After we've completed the five simple steps to create our HID code set, you'll see that HIDmaker FS is just as much a USB teaching tool as it is a USB code generator. The descriptors that HIDmaker FS generates contain guidance, as well as USB-centric descriptor information.

The first HIDmaker step we take is to describe and specify a home for our project, just like I've done in **Screenshot 1**. I've used familiar names and descriptions so that we can easily pick them out in the descriptors. The Vendor ID (VID) and Product ID (PID) belong to Microchip. We can use them for prototype device use only and — like my naming convention — we can easily spot the PID/VID combination as we examine the descriptor content. The device description strings are optional. However, the string information we have provided will be included in the descriptor code.

Please turn your attention to **Screenshot 2**. Our simple HID peripheral device design will consist of a single USB-powered Configuration, which we will call *Config_NV_1*. Note the maximum current requested from the USB host is set for 20 mA. Our *Config_NV_1* Configuration will support only one Interface: Interface 0. It's identified as *Config_NV_1* Interface0.

Interface 0 is associated with Endpoint *EP1 In*. In the world of USB, IN and OUT are always relative to the host. So, data coming from the HID peripheral device will originate at the peripheral's *EP1 In* Endpoint. Endpoints are usually hardware buffers that support the movement of data between the host and the peripheral functions. Note that our *EP1 In* Endpoint is an Interrupt type. That means it can only respond with the data it contains if the host PC requests that it do so. Thus, the peripheral device function must attempt to always have fresh data ready for the host when it asks for it. That's where the "interruption" is inferred. According to the Interval — mS setting — this HID device must be ready 10 mS following the last Interrupt transfer request.

■ SCREENSHOT 2. The HID peripheral device can use the full functionality Endpoints EP1 and EP2. It's important to remember that the INs and OUTs of USB are relative to the host device.



Screenshot 2 enforces the fact that a HID class device uses Control and Interrupt methods to transfer data. The Control Endpoint *EP0* is always present as it is the conduit in which initial communications is established between the USB host and the peripheral device. A look at the selectable IN Endpoints tells us that the peripheral device is not allowed to use the *EP0 In* Endpoint to transmit data.

The data to be handled by the Endpoint is set up in the portion of HIDmaker FS captured in **Screenshot 3**. The *Input* Data Type says that this data element can only flow from the peripheral to the host device. I've chosen to take the default Usage Info selection as we aren't in need of identifying the data with a particular function or device. A Usage ID of 0x01 and a Usage Page of 0xFF00 map to Vendor Specific descriptions and that's just fine for us at this point. I forced the default Logical MIN (0x00) and Logical MAX (0xFF) values of the data item by specifying the data as an eight-bit data element. I can guarantee that you'll see *nv_data8* again in our generated HID code and in the application data transfer traces as the Report will contain a byte of data we have defined as *nv_data8*.

Screenshot 4 presents us with multiple compiler choices. Are you more comfortable with using Basic? Then you will want to select PICBASIC PRO. If you like the PIC-oriented macro approach to programming, choose CCS C. I'm planning on comparing the descriptors generated by HIDmaker FS with the PICDEM FS descriptors in the MCHPFSUSB Framework. So, I've clicked on Microchip C18. I would normally take Visual Basic 6 as my Windows programming language. However, lately I've been doing my Windows application programming using Visual C++, which is a component of Visual Studio 2008 Standard.

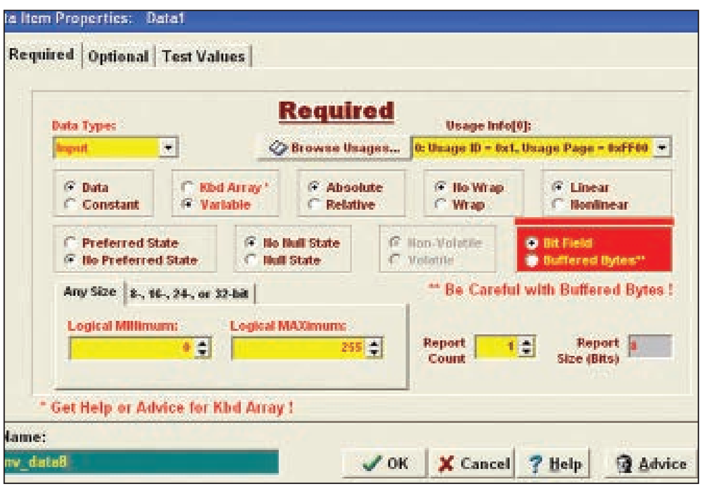
Once you've made your compiler selections and issue the *Next* click, **Screenshot 5** will inform you that you've got code to compile. In our case, we'll need Microchip's C18 on the PIC side and a suitable version of Visual Studio on the PC side.

Our HIDmaker FS descriptor set includes a Device Descriptor, a Configuration Descriptor, an Interface Descriptor, a HID Descriptor, an Endpoint Descriptor, a Report Descriptor, and the string tables. Once you see the Descriptors for what they are, USB becomes less mysterious. With that, let's take a look at them.

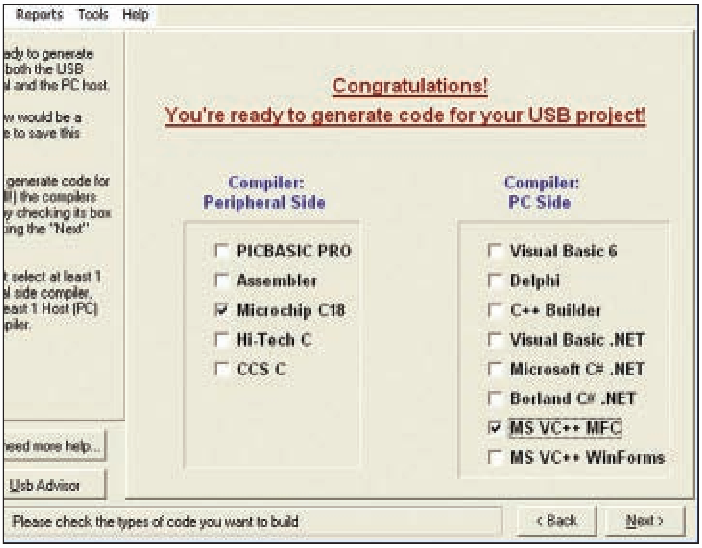
The Device Descriptor is all about the device. Thus, a USB device can only be associated to a single Device Descriptor. Let's look at the Descriptor HIDmaker FS generated for us:

```
//from HIDmaker FS usb18.inc
#define DSC_DEV       0x01

//from HIDmaker FS pdconsts.inc
```

```
; Project-specific constants that pertain to the
; whole device
#define  EP0_BUFF_SIZE    8  ; 8, 16, 32, or 64
#define  NUM_CONFIGURATIONS   1

;=================================================
; DEVICE DESCRIPTOR:
;=================================================
DeviceDescriptor:
 global DeviceDescriptor
     retlw   0x12      ;Length of this Device
                       ;Descriptor
     retlw   DSC_DEV   ;bDescriptorType = 1 for
                       ;Device Descriptor
     retlw   0x10      ;USB Spec Version (1.1). 2
                       ;BCD bytes stored in a Word
                       ;variable
     retlw   0x01
     retlw   0x00      ;bDeviceClass = 0 for HID
                       ;class, which is set in
                       ;Interface Descriptor
     retlw   0x00      ;USB Subclass code, if
                       ;applicable
     retlw   0x00   ;bDeviceProtocol code,
                    ;if applicable
     retlw   EP0_BUFF_SIZE    ;Max packet size for
                              ;EndPoint 0
     retlw   0xD8   ;Vendor ID (2 hex bytes)
     retlw   0x04
     retlw   0x0C   ;Product ID (2 hex bytes)
     retlw   0x00
     retlw   0x01   ;Device release number
                    ;(2 hex bytes)
     retlw   0x00
```



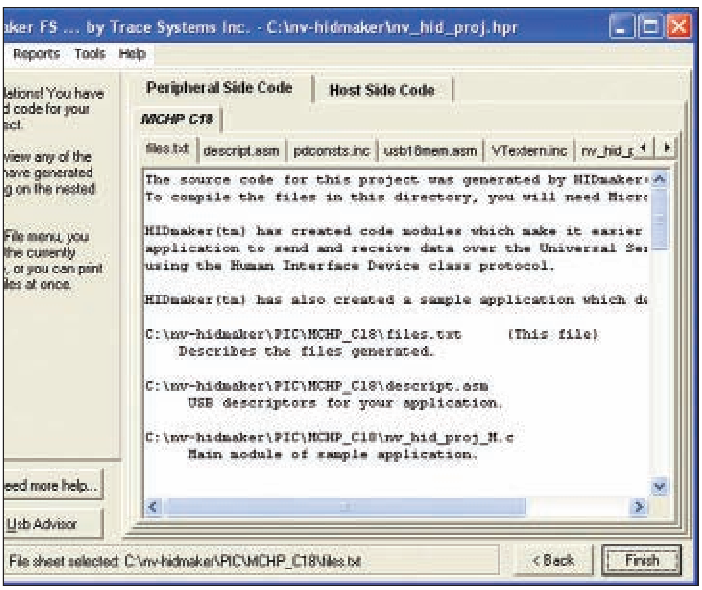
■ SCREENSHOT 3. The really cool thing about this window is that you can click on the field and then get *Advice* on how to complete the field with a second click.



■ SCREENSHOT 4. Way back when, I discovered that having a copy of Visual Basic was just as important as having one or more of the PIC compilers shown here. Over the years, I've written code with all of the Peripheral side compilers/assemblers and four of the PC side compilers.

```
     retlw   0x01   ;Manufacturer name string
                    ;(gets own String Descriptor)
     retlw   0x02   ;Product Name string (gets own
                    ;String Descriptor)
     retlw   0x00   ;Serial Number string (gets
                    ;own String Descriptor)
     retlw   NUM_CONFIGURATIONS
               ;No. Configurations for this device
```

As you can see, HIDmaker FS delivers the descriptors to us in assembler format. The *retlw* (Return with literal in W) instructions infer that a table lookup algorithm is used to access the descriptor data. I'm not going to insult your intelligence as I'm sure you can pick out the data we entered in the screenshots. However, easy pieces of data to recognize are the VID and PID we entered in **Screenshot 1**. The string data we stuffed into **Screenshot 1** is referenced in the Device Descriptor and can be found in the descriptor code in *retlw* lookup table format.



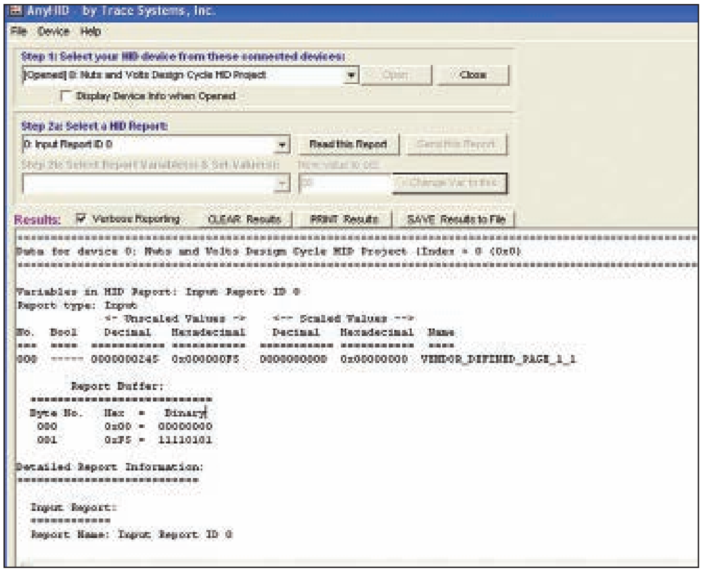
The MCHPFSUSB Framework presents the Device Descriptor in a C-compatible format. I've pulled in the Device Descriptor constant definitions from the usb_config.h file for you:

```
//from MCHPFSUSB Framework usb_config.h
#define USB_EP0_BUFF_SIZE          8
#define USB_USER_DEVICE_DESCRIPTOR &device_dsc

/* Device Descriptor */
ROM USB_DEVICE_DESCRIPTOR device_dsc=
{
     0x12,   // Size of this descriptor in bytes
     USB_DESCRIPTOR_DEVICE,  // DEVICE descriptor
                             // type
     0x0200,          // USB Spec Release Number
                      // in BCD format
     0x00,            // Class Code
     0x00,      // Subclass code
     0x00,      // Protocol code
     USB_EP0_BUFF_SIZE,   // Max packet size
                      // for EP0, see usb_config.h
     0x04D8,          // Vendor ID
     0x003F,          // Product ID: Mouse in a
                      // circle fw demo
     0x0002,          // Device release number in
                      // BCD format
     0x01,            // Manufacturer string
                      // index
     0x02,            // Product string index
     0x00,            // Device serial number
                      // string index
     0x01             // Number of possible
                      // configurations
};
```

I think you can easily see the similarities in the actual data content of the HIDmaker FS and the MCHPFSUSB Framework Device Descriptors. Both of the Descriptors perform the same task. They provide the necessary information to describe the HID peripheral device to the host. The Configuration Descriptor and Interface Descriptor code we'll look at next is a result of the information we entered into the HIDmaker FS window captured in **Screenshot 2**. Once again, you can correlate the FS-generated Configuration and Interface Descriptors with the information we provided to HIDmaker FS in **Screenshot 2**:

```
;================================================
; CONFIGURATION DESCRIPTOR:  Config1
; Configuration 1
;================================================
Config1:
 global Config1
     retlw   0x09    ;Length of this Configuration
                     ;Descriptor
     retlw   DSC_CFG    ;bDescriptorType = 2 for
                        ;Configuration Descriptor
Config1Len:
   global Config1Len
     retlw   low   ((EndConfig1 - Config1)/2)
;Total Config Length
     retlw   high ((EndConfig1 - Config1)/2)
     retlw   0x01   ;Number of interfaces this
                    ;configuration supports
     retlw   0x01   ;Configuration ID, used in
                    ;Get_Configuration and
```

■ SCREENSHOT 5. When you see this window, things are good and going to get better. HIDmaker FS sets up complete projects on the PIC and PC sides. All we have to do now is open the projects and compile them.



■ SCREENSHOT 6. HIDmaker FS allows us to specify a test value for the data we define within it. I allowed HIDmaker FS to randomly set *nv_data8* to a value of 245 decimal.

```
                  ;Set_Configuration requests
    retlw   0x03  ;Configuration Name string
                  ;(gets own String Descriptor)
    retlw   0x80  ;Bitfield: flag bits for
                  ;Self-Powered & Remote Wakeup
    retlw   0x0A  ;Max current required from
                  ;USB for this config: =
                  ;milliAmps * 2
```

About the only thing you can't readily decipher is the 0x80 flag byte which is technically the *bmAttributes* field. The most significant bit in the *bmAttributes* field is set to indicate that the HID device is powered from USB. According to **Screenshot 2**, the Remote Wakeup feature is disabled and that's backed up by a cleared bit 5 in the *bmAttributes* field. The Interface Descriptor is just as easy to understand as the Configuration Descriptor:

```
;================================================
; INTERFACE DESCRIPTOR:  Interface0
; Config1, Interface 0, Alternate 0
;================================================
Interface0:
 global Interface0
    retlw   0x09   ;Length of this Interface
                   ;Descriptor
    retlw   DSC_INTF   ;bDescriptorType = 4 for
                       ;Interface Descriptor
    retlw   0x00   ;Interface ID no.
    retlw   0x00   ;If >0, this  Interface
                   ;Descriptor is an alternate
                   ;setting
    retlw   0x01   ;No. endpoints supported over
                   ;and above Endpoint 0
    retlw   0x03   ;HID is class 03h, & is
                   ;declared HERE
    retlw   0x00   ;This field may specify a
                   ;subclass within a class
    retlw   0x00   ;May specify a protocol for
                   ;classes defined by the
                   ;interface
    retlw   0x04   ;Interface name string (gets
                   ;own String Descriptor)
```

All you need to walk away with from the Interface Descriptor is the number of Endpoints (other than EP0) that are supported and that the HID class is specified here. The next decriptor we'll examine is the HID Descriptor. In the context of our discussion, a HID Descriptor is used to lay out the number, type, and size of Report descriptors that are associated with a HID device:

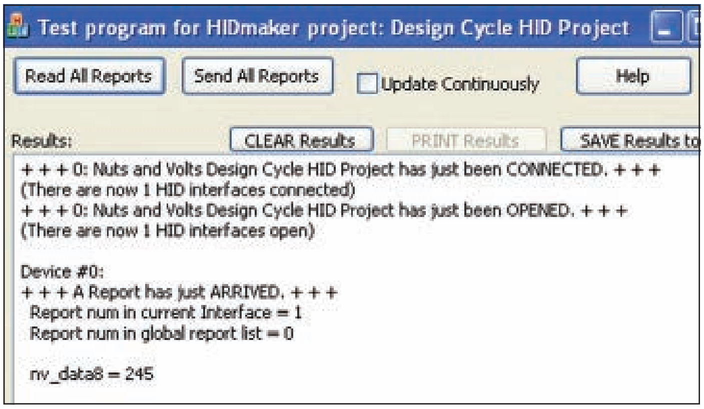
```
;================================================
; HID DESCRIPTOR:  HID0
; Config 1, Interface 0, Alt 0 HID Descriptor
;================================================
HID0:
HID_Descriptor1:
 global HID_Descriptor1
 global HID0
    retlw   0x09   ;Length of this HID
                   ;Descriptor
    retlw   0x21   ;bDescriptorType = 21h for HID
                   ;Descriptor
    retlw   0x10   ;HID Spec release number, in
                   ;BCD
    retlw   0x01
    retlw   0x00   ;Country code (BCD) for
                   ;localized hardware, if
                   ;supported.
    retlw   0x01    ;No. subordinate Report
                    ;Descriptors under this HID
                    ;descr.
    retlw   0x22    ;Report Descriptor type
    retlw   low   ((EndReport1 - Report1)/2)
                    ; Length of Report Descriptor
    retlw   high ((EndReport1 - Report1)/2)
```

Our HID Descriptor is relatively simple as we're not describing human-associated physical things that can be associated with the HID class. The Descriptor is basically telling the world that there is one Report Descriptor to look out for and how long it will be.

In my opinion, the smallest descriptor contains the most useful information. Let's break down the Endpoint Descriptor:

```
; For Configuration 1:
; ====================
#define  NUM_INTERFACES   1
#define  C1_MAX_EP_NUMBER   1
; Define Endpoint size constants for
; Configuration 1:

; C1_In_Endpoints:
#define  EP1_IN_BUFF_SIZE    64   ; 8, 16, 32, or
64 if used;  0 if EP is unused

;================================================
; ENDPOINT DESCRIPTOR:  EndPoint1In
; Config 1, Interface 0, Alt 0  EndPoint1In
;================================================
EndPoint1In:
 global EndPoint1In
    retlw   0x07  ;Length of this Endpoint
                  ;Descriptor
    retlw   DSC_EP    ;bDescriptorType = 5 for
                      ;Endpoint Descriptor
    retlw   0x81  ;Endpoint number & direction
    retlw   0x03  ;Transfer type supported by
                  ;this Endpoint
    retlw   EP1_IN_BUFF_SIZE
                  ;Max no. data bytes this
                  ;Endpoint can transfer in a
                  ;TRANSACTION
    retlw   0x00      ;
    retlw   0x0A      ;Max latency in
                              ;millisec, 10-255
                              ;for low speed
                              ;devices
```

The *bEndpointAddress* field contains 0x81. The



■ SCREENSHOT 7. The source code for this HIDmaker FS-generated PC C application can be used as a framework to code your PC-side HID application.

Endpoint is an IN type as the most significant bit is set. The Endpoint Address is contained within the four least significant bits and cyphers out to 0x01. The Transfer Type is defined as 0x03 which equates to Interrupt. You can also pick out our 10 mS interval value that was entered in **Screenshot 2**.

MOVING nv_data8

HIDmaker FS contains a suite of test applications that verify correct operation of the code. One of those applications is called AnyHID. I've captured an AnyHID session that picked up the Report data returned from our HID class PICDEM FS USB Demo Board. The value of 245 decimal gleaned from the HID Report is the random value that HIDmaker FS assigned to our data variable *nv_data8*.

The PC C application that HIDmaker FS generated is more specific to our PIC18F4550-based HID peripheral device. **Screenshot 7** shows that same random value of 245 decimal directly associated with our data variable *nv_data8*. The results in **Screenshot 7** come courtesy of the HIDmaker FS-generated Visual C++ HID application.

EIGHT BITS DOWN - EIGHT BITS TO GO

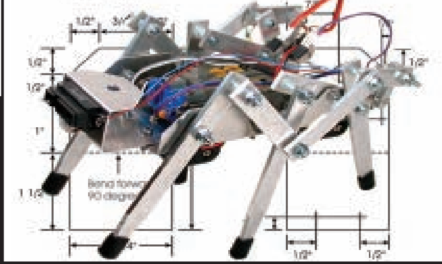
We've worked our way through an eight-bit USB HID implementation using Dr. Bob's HIDmaker FS. When we meet again, we'll put the MCHPFSUSB Framework to work against a 16-bit PIC24FJ256GB110 and dig up some more HIDden treasure. In the meantime, you can add HIDmaker FS and the PIC 18F4550 to your Design Cycle. **NV**

SOURCES

HIDmaker FS
Trace Systems
www.tracesystems.com

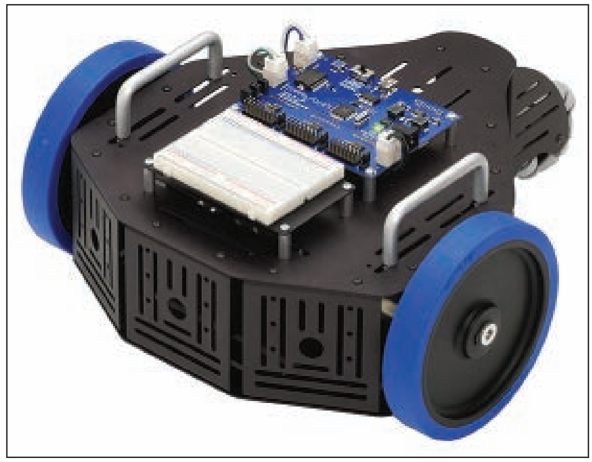
MCHPFSUSB Framework
MPLAB C Compiler for PIC18 MCUs
Microchip
www.microchip.com

Visual Studio 2008 Standard
Microsoft
www.microsoft.com



■ BY VERN GRANER

THE PARALLAX STINGRAY ROBOT



Stronger than a BOEBOT, more powerful than a pen-wielding Scribbler, easier to carry than a QuadRover, the Parallax Stingray mobile robotic platform has landed!

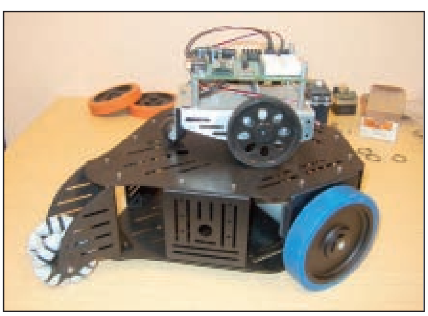
FISHING FOR THE STINGRAY

I first heard rumors about the Stingray in a thread on the Parallax Forums. Someone had noticed a new robot acting as the "Stage" for the Parallax PING)) sensor bracket. With the cat out of the bag, Chris Savage gave everyone some nice sneak peeks at the upcoming robot Parallax was gearing up to produce. After a bit of prompting, he posted some intriguing pictures of the prototypes (**Figures 1A** and **1B**). This bot seemed to really fill a niche as it was larger and stronger than the BOEBOT or Scribbler (**Figures 2A** and **2B**), yet not so big as to require multiple people to lift it and a truck to carry it.

Having built some large robots based on recycled wheelchair chassis (see "Evolution of the Boogiebot," *Nuts & Volts* October '07) I know that, though really big robots can be lots of fun, they are also a pain in the ... back. When you have to lift 100 pounds of solid metal and lead-acid batteries in and out of a car trunk a few times, you really start to appreciate smaller bots.

■ FIGURE 1A. Stingray Prototype "Alpha."

■ FIGURE 1B. Stingray Prototype "Beta 1 and 2."

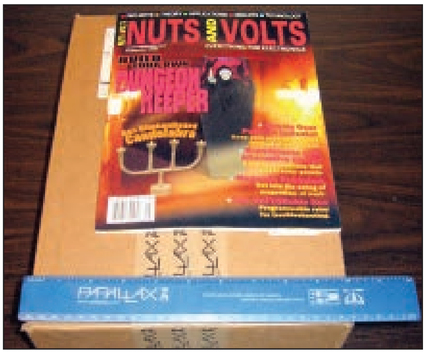


■ FIGURE 2A For scale, a Parallax BOEBOT is perched atop the Stingray.

■ FIGURE 2B. A Parallax Scribbler robot easily fits inside the Stingray's roomy chassis.

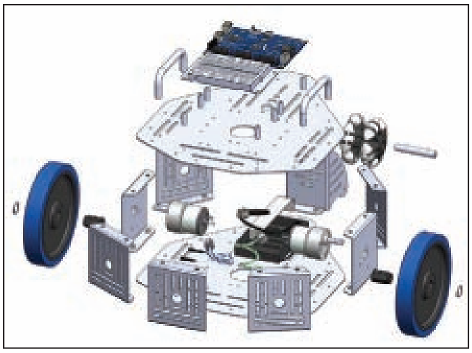
PULL THE TRIGGER?

Since I've built both big and small bots, I decided there was room in my menagerie for a Stingray of my own to experiment on. I contacted Parallax to see when they would be available and (most importantly) to find out the price. I was hoping the Stingray would be cheap enough to make them accessible even to folks without deep pockets. I called and found out that the Stingray was already in stock and priced at just under $300. I ordered my Stingray and it shipped the same day.



■ FIGURE 3. The Stingray arrives from Parallax (ruler and magazine shown for scale).

■ FIGURE 4. All the parts from the box spread out on a table.



■ FIGURE 5. Exploded view of the Stingray from the assembly documentation.

Before my Stingray arrived, I decided to document every aspect of its journey from shipping box to completed bot. What follows is a front row seat to the complete assembly of the Stingray robot.

UNBOXING DAY

The Stingray arrived in a mid-sized shipping box (**Figure 3**). I opened it and scooped out all the packing peanuts to discovered a shipping manifest, a nice glossy catalog of Parallax products and a smaller white folding box that contained all the Stingray parts. It seemed like a surprisingly small box, but after opening it, I discovered the reason is that the Stingray comes "flat packed" with all the parts in individual plastic bags to keep the anodized aluminum parts from scratching each other in transit. I spread out all the parts on the table (**Figure 4**) and did a quick inventory. Everything was present and accounted for, so it was time to build it.

PUTTING IT ALL TOGETHER

The kit comes with a complete set of printed illustrated instructions including some very nice exploded views (**Figure 5**). It even includes just about all the tools you'll need to put the unit together. I invited neighbor and colleague Marvin "Professor Conrad" Niebuhr over to assist in the robo-build (**Figure 6**).

The build was just about as straightforward as you would expect with the very detailed instructions guiding us along the way. We went from the delivered box to completed bot in about three hours. There were no missing parts and all the holes lined up exactly so we didn't have to drill anything out or modify any of the components. I have to say it's quite nice to get something where the care in the design is so obvious.

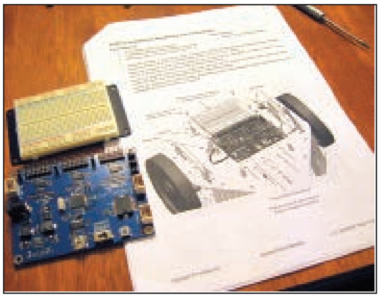
After a virtually flawless mechanical assembly (the only goofs were our own!), it was time to install the electronics (**Figure 7**). Though Parallax could have simply used a BASIC Stamp to drive the Stingray, they went all-out and created a brand new robot control board based on their new Propeller chip.

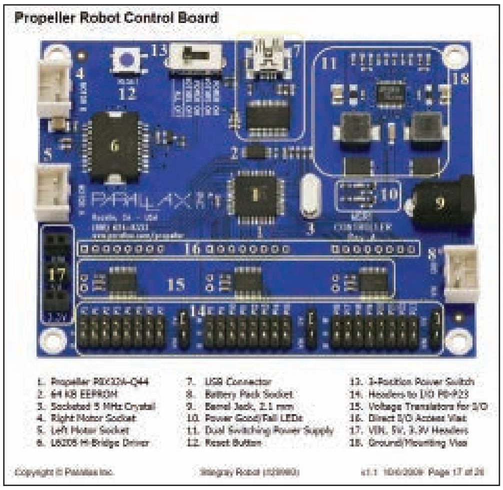
THE MSR1 CONTROLLER

To me, one thing that really sets this bot apart from others is the new MSR1 controller (**Figure 8**). This board really surrounds the Propeller chip with some extremely useful and much needed hardware. Besides including an on-board L6205 H-bridge to control the two gear head motors, they have also placed voltage translators that are used to interface the 3.3V native signals of the Propeller to the more common 5V signals used by many off-the-shelf accessories and sensors. An on-board dual switching

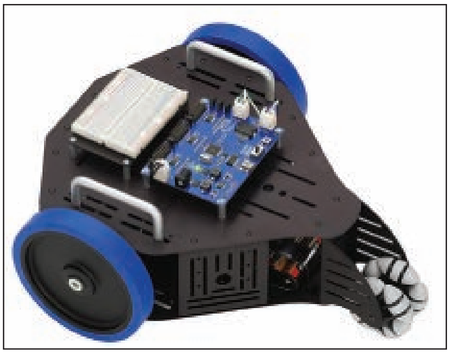
■ FIGURE 6. The main chassis parts laid out and ready to assemble.

■ FIGURE 7. The MSR1 controller and the breadboard ready to be attached to the Stingray.

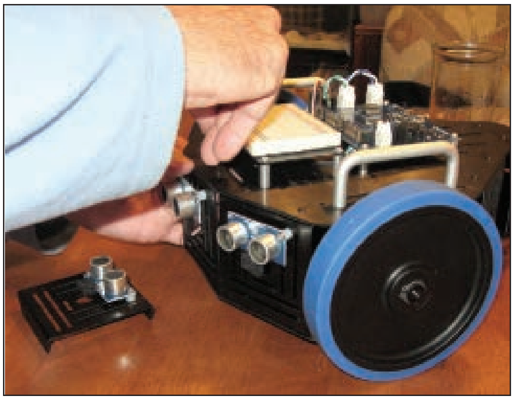




■ FIGURE 8. Detailed view of the new MSR1 robot controller board.



■ FIGURE 9. The mounted MSR1 board and adjacent breadboard ready for experimentation.



■ FIGURE 10. Adding three PING)) sonar sensors to help the Stingray avoid collisions.

■ FIGURE 11. The multi-directional tail wheel can roll in any direction.

power supply and 24 three-pin "servo" style headers (broken up into three banks of eight) make plugging in components a snap. To top it off, they doubled the amount of memory that is typically available on most Propeller prototyping boards. Parallax also includes a nice-sized breadboard so the Stingray is ready for experimentation right away (**Figure 9**).

"TWEEN" BOT

To me, the Stingray fits perfectly between the big bots and the plethora of small table-top robots driven by continuous-motion servos. Not only does the Stingray posses wicked head-turning good looks, its gear head motors are both quite strong and fast. I was rather surprised the first time I let this thing run around on the floor (it almost took out my cat)! One of the things I did was add three PING)) sonar sensors (**Figure 10**) so the bot would have a chance of detecting and avoiding walls (and cats) because when it gets moving, it builds up a goodly amount of kinetic energy.

The included BaneBots rubber wheels are a good compliment to the gear head motors as they are very "grippy." The bot can literally turn on a dime. The multi-directional tail wheel is not only cool to look at, but it feels like it's almost friction free. I've had other "tail dragger" style mini robots and not only does the tail wheel impact battery life, it can also alter dead-reckoning navigation if the extra friction causes the drive wheels to slip. The multi-directional tail wheel (**Figure 11**) is a very cool improvement.

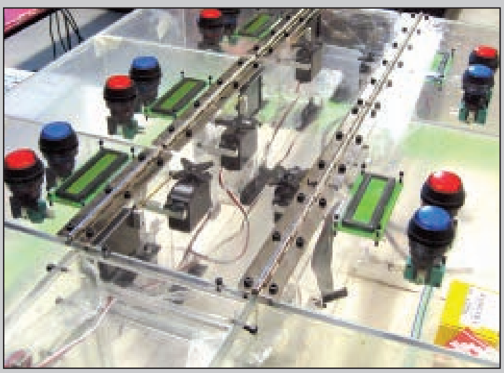
ITS ALL GOOD ... OR IS IT?

Though I am obviously smitten with my new Stingray bot, you have to be thinking, "There's got to be something you would improve, right"? Okay, I'll admit there are a couple of minor things I would love to see improved. For starters, the battery box is pretty much unreachable once it's screwed down in its default location in the inside/center of the bot. This makes removing the batteries for charging rather difficult. Though I was able to both extract and insert batteries using just two fingers and quite a bit of patience (and maybe a few mumbled words), I ended up leaving out two of the screws on one of the mount plates so I could more readily get to the batteries by swinging open my makeshift "door" (**Figure 12**).

The batteries called for in the assembly sheet are 1.2V rechargeable NiMh AA cells. I would love to see the MSR1 contain a battery charging circuit designed to charge this style of battery directly. As it stands, when you plug in the external power 2.1 mm plug, it bypasses the batteries instead of charging them.

So, be aware that you can't charge up your Stingray by plugging it into a wall wart overnight. On the upside, the bot is designed to run from a 7.2V power source. So,

Speaking of Propellers ...



If you find the Parallax Propeller chip is interesting and you'd like to get a bit more info about it and how it can be used, there's a new book that you might be interested in reading. Though I only had a small part in its creation (1/12th part to be exact!), I am honored to be included with the likes of Chip Gracy, Andre' Lamothe, Hanno Sander, and other notable Propeller heads in the creation of "Programming and Customizing the Multicore Propeller" from McGraw Hill. The book is available for pre-order from: **www.amazon.com/Programming-Customizing-Multicore-Propeller-Parallax/dp/0071664505** and should be available soon at other technical book stores around the country. The section I authored explores using the Propeller as the center of an intelligent HVAC "green house" design. If you read the book, please feel free to let me know what you think by sending an email to vern@txis.com.

if you plan to use your Stingray for extended periods of time (for example, in a classroom setting), you might want to swap the NiMH AA cell pack for some more readily-available 7.2V RC car rechargeable packs with higher amp-hour ratings and external chargers. This way, you could have one pack in the bot and one on standby being charged.

SUMMING IT UP

I feel the Stingray is an amazing piece of engineering and will enjoy great success. It's just a solid feeling robot with excellent looks and lots of room for expansion and experimentation (**Figure 13**). The dual aluminum carry handles on the top make it easy to bring along with you. I've carried it into restaurants and other places where my robo-buds hang out, and I've already had three people on three separate occasions stop me and ask about it.

With its torquey gear-head motors, grippy rubber wheels, sleek all-metal dual-deck chassis with loads of attachment points, the sexy multi-directional tail wheel and the high-powered multi-core processor, the new Parallax Stingray just oozes style! If you end up with a Stingray, please let me know as I'd love to hear how you like it and put it to use. As always, you can reach me via email at vern@txis.com. **NV**

■ FIGURE 12. With two screws removed, a battery access door is created.

■ FIGURE 13. A test-fit of an accessory I plan to add to my Stingray to give it some STING!

RESOURCES

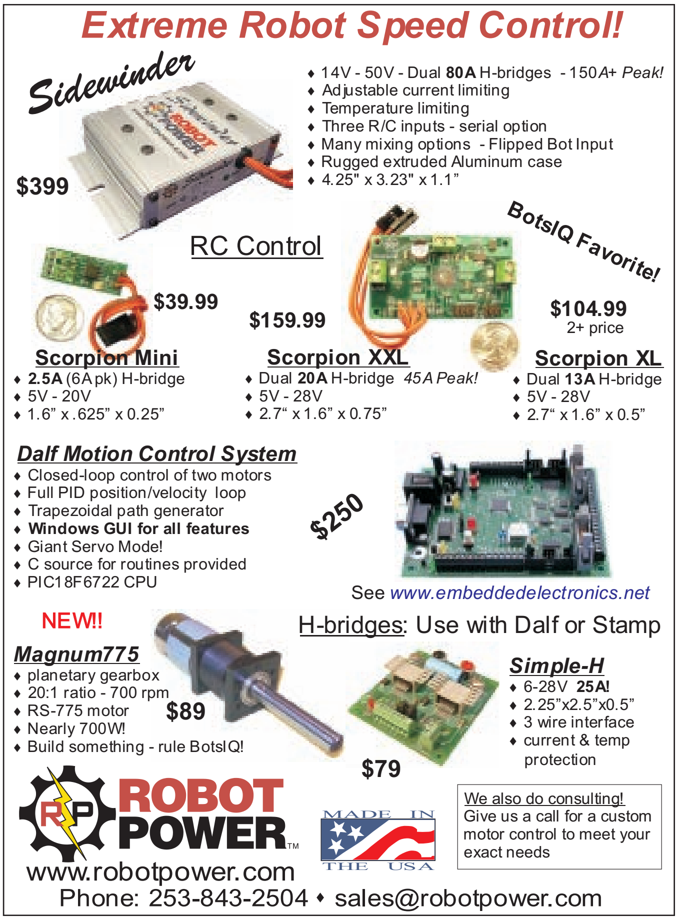
Parallax Stingray Robot:
www.parallax.com

Stingray discussion on Parallax Forums
http://forums.parallax.com/forums/default.aspx?f=10&m=391099

Evolution of the Boogiebot, *Nuts & Volts* October 2007:
http://nutsvolts.texterity.com/nutsvolts/200710#pg84

Marvin "Professor Conrad" Niebuhr's site:
www.professorconrad.com

Programming and Customizing the Multicore Propeller
www.amazon.com/Programming-Customizing-Multicore-Propeller-Parallax/dp/0071664505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Scorpion XXL
♦ Dual 20A H-bridge 45A Peak!
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♦ Dual 13A H-bridge
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■ BY RON HACKETT

INTERFACING SEVEN-SEGMENT LED DISPLAYS

This time, we're going to experiment with interfacing seven-segment LED displays with PICAXE processors. To explore the basic concepts involved, we'll begin with the simplest case: interfacing a single-digit LED display with a 20M processor. Once we have covered the basics, we'll examine the process of LED display multiplexing, and interface a four-digit display with our 28X1 master processor circuit. In the next Primer installment, we'll turn our attention to the MAX7219 LED display driver, which greatly simplifies the circuitry and software normally required to interface multiple-LED displays with a microcontroller. At that time, we'll take advantage of this simplification to develop a stand-alone, four-digit peripheral LED display for use in our upcoming projects.

INTERFACING A SINGLE-DIGIT LED DISPLAY

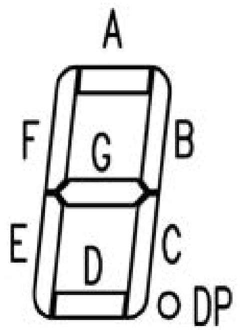
Most seven-segment LEDs are either "common cathode" or "common anode" displays. These terms simply indicate whether the cathodes or the anodes of the segments are connected together. For our first experiment, we will be using a common cathode display so we will connect an output pin of the 20M to each segment (through a current-limiting resistor). We'll then connect the display's common cathode pin to the breadboard's ground rail. All seven-segment LED displays use the same alphabetic order when referring to the individual segments. This standard labeling convention is shown in **Figure 1**.

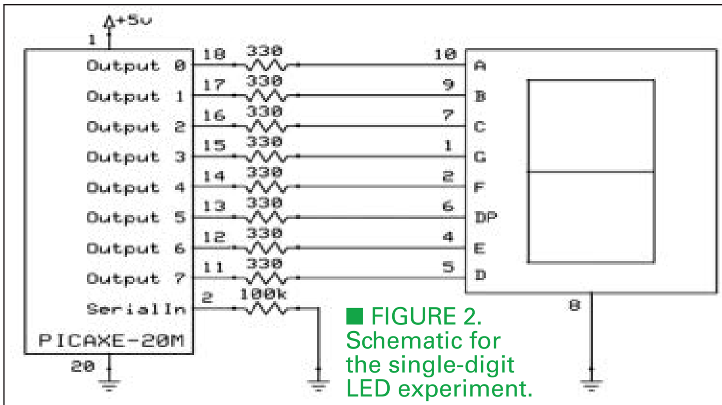
The schematic for our first experiment is presented in **Figure 2**; the Parts List is in **Figure 3**; and the pin-out of the single-digit LED is shown in **Figure 4**. As you can see in the schematic, I haven't included the standard PICAXE programming circuitry. We're going to be using the SUSB-01 programming adapter that we developed in the previous installment of the Primer.

Since the required programming circuitry is self-contained on the SUSB-01, I decided to omit it from the LED display schematic. Also, the specific connections from the 20M outputs to the LED segments were chosen to simplify the breadboard wiring. Finally, in **Figure 4** you can see that the display's pin-out includes two ground pins (pin 3 and pin 8). It's not necessary to connect both of them to ground — either one will do the job.

Figure 5 is a photo of the completed breadboard circuit for our first experiment. The current-limiting resistor that connects to the display's decimal point is the only one that couldn't be placed right in line with its corresponding output pin. (If

■ FIGURE 1. Standard LED segment labeling.





■ FIGURE 2. Schematic for the single-digit LED experiment.

it had been, it would have connected to ground at pin 3 of the display, so it would be impossible to raise that line high to light the decimal point.)

Whenever you work with LED displays (or any device that consumes a fair amount of power), you need to make sure you don't exceed the current capabilities of the processor. **Figure 6** presents the relevant data for selected PICAXE processors. The 330Ω resistors that we are using limit the current through each segment of the LED to less than 10 mA. As you can see in **Figure 6**, 20M output pins are capable of sourcing up to 25 mA each, so we are well within the limits of the individual pins. However, it's also important to determine whether you are exceeding the overall limit of the output port, or the chip itself. In our case, if all eight segments are lit at the same time, we are still drawing less than 80 mA, so we are well within those limits, as well.

The major task that a seven-segment LED driver program needs to accomplish is to convert the value to be displayed to the correct pattern of segments that corresponds to that value. For example, if we want to display the digit "3," we need to light segments A, B, C, D, and G. This conversion process is actually simpler than it sounds, but to understand how it works you need to be somewhat comfortable with the binary number system (upon which all microprocessors are based). There isn't space to get into the details here, but if you do a quick search on "binary number system," you will find many on-line tutorials on the subject.

Once you have a basic understanding of binary arithmetic, we need to briefly discuss the 20M "special function variable" called "outpins" which can be used to simultaneously define the high/low levels of all eight pins of the 20M's output port.

I'll use binary numbers to demonstrate how the "outpins" instruction functions because (believe it or not) it's easier to understand that way!

To begin with, whenever you want to use a binary number in a PICAXE program, you need to preface it with a "%" character. For example, "let myVar = %00000111" assigns the specified eight-bit binary number (which corresponds to the decimal number 7) to myVar. (If you don't include the "%" character, the number is interpreted as the decimal number "one hundred eleven.") Extending the same concept to outpins, if we issue an "outpins = %00000111" command we're telling the compiler that you want outputs 2, 1, and 0 to be high, and outputs 7-3 to be low. This makes outpins very powerful — without it, we would need to issue the correct combination of eight high and low commands to accomplish the same goal.

To see how all this works, consider the data presented in **Figure 7**. (The easiest way to understand **Figure 7** is "from the bottom up.") The bottom two rows show the same pairing between the 20M outputs and LED segments that we saw earlier in the schematic. The zeros and ones in the body of the table indicate which segments need to be turned on to display any given digit (1 = on and 0 = off).

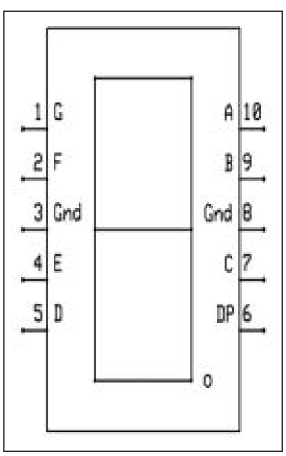
For example, to display the digit "4," we need to light segments B, C, F, and G, so a "1" is placed in the cells that correspond to those four segments and a "0" is placed in all the other cells for the digit "4." The resulting eight-bit binary number is then converted to its decimal equivalent in the right-most column. We will use those decimal values in our program to display the value of any given one-digit number.

■ FIGURE 3. Parts List for the single-digit LED experiment.

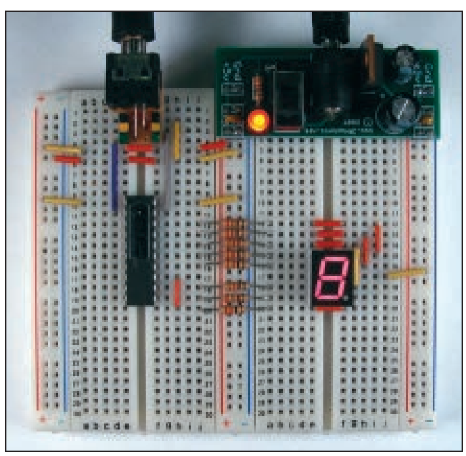
PICAXE-20M Processor
LED, Single-Digit 7-Seg. Display
Eight Resistors, 330, 1/4 watt
One Resistor, 100 k, 1/4 watt

The software for our experiment (LED7X1.bas) can be downloaded from the *N&V* website. (While you're there, also download the LED7X4 program that we will be using in our second experiment.) LED7X1 is very simple; it just counts from 0 to 9 in an infinite loop and displays the corresponding values on the LED. The heart of the program is a "lookup" command that enables us to retrieve the correct decimal value we need for each digit. The syntax of the lookup command is "lookup offset, (data0, data1, ... dataN), variable" — see the documentation in Part II of the manual for details. For our purposes, the necessary command is "lookup value, (215, 6, 203, 143, 30, 157, 221, 7, 223, 159), segs." The command is zero-based so if value = 0, then segs = 215; if value = 1, then segs = 6; if value = 2, then segs = 203; etc. Of course, you could accomplish the same thing with 10 different "if" statements, but it would be much more work.

Download the program and give it a try. You will probably notice that I didn't do anything with the decimal point in this simple example. As a programming challenge, see if you can turn the decimal point on for the even digits and off for the odd ones. (Hint: It can be done by adding one "if" statement in the loop.) Once you are satisfied that you understand how the program functions, we're ready to



■ FIGURE 4. Pinout of the single-digit LED display.



■ FIGURE 5. Breadboard setup for the single-digit LED experiment.

	Chip	Port	Pin
08M, 14M, 20X2	95mA	90mA	25mA
20M, 28X2, 40X2	250mA	200mA	25mA

■ FIGURE 6. PICAXE maximum current capabilities.

Displayed Digit	Binary Value	Decimal Value
0	1 1 0 1 0 1 1 1	215
1	0 0 0 0 0 1 1 0	6
2	1 1 0 0 1 0 1 1	203
3	1 0 0 0 1 1 1 1	143
4	0 0 0 1 1 1 1 0	30
5	1 0 0 1 1 1 0 1	157
6	1 1 0 1 1 1 0 1	221
7	0 0 0 0 0 1 1 1	7
8	1 1 0 1 1 1 1 1	223
9	1 0 0 1 1 1 1 1	159
Outputs	7 6 5 4 3 2 1 0	
Segments	D E DP F G C B A	

■ FIGURE 7. Binary/Decimal output values for the single-digit display.

move on to our next experiment.

INTERFACING A FOUR-DIGIT LED DISPLAY

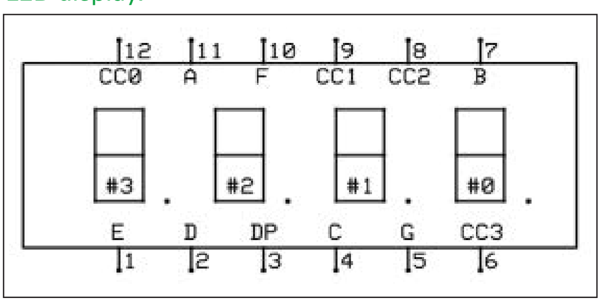
This time around, we're going to interface a four-digit LED display to our 28X1 master processor but before we do, there are two issues that need to be addressed. First, if we tried to directly interface four of the single-digit displays that we just used, we would need a total of 32 output pins to accomplish the task. Even though the 40X2 processor has a total of 32 I/O pins, we still would have a major problem to overcome. Since our single-digit display can consume almost 80 mA, four of them would require 320 mA and this exceeds the capabilities of every PICAXE processor. Of course, we could increase the size of the current-limiting resistors, but our display would become correspondingly dimmer.

There's a much better solution to this problem. It's called display multiplexing and it involves sequentially powering only one digit at a time. The sequencing is rapid enough so that all four digits appear to be lit simultaneously — even though that's not the case. They are blinking so rapidly that our persistence of vision leads us to believe that they are all powered at the same time. (This phenomenon is analogous to our misperception that the image in a movie is actually "moving," rather than being made up of a sequence of rapidly changing still photos.) **Figure 8** presents the pin-out of the 4-digit common-cathode display that we will be using (which is also available on my website). Because a common-cathode display is required by the MAX7219 that we will be using in our next installment, we'll be able to re-use the same display. As you can see in **Figure 8**, there's only one pin (not four) for each display segment (A, B, etc.). This is another major advantage of display multiplexing; four digits only require 12 output pins (eight display segments and four common cathodes), rather than the 32 needed by four individual displays.

In order to use display multiplexing, our program must include some method of keeping track of the four individual digits that are to be displayed "simultaneously" — let's call them digit3, digit2, digit1, and digit0. Display multiplexing is implemented in a short loop that accomplishes the following tasks:

- Digit3 is loaded into the output port.
- Only the cathode for LED 3 is grounded.
- Digit2 is loaded into the output port.
- Only the cathode for LED 2 is grounded.
- Digit1 is loaded into the output port.
- Only the cathode for LED 1 is grounded.
- Digit0 is loaded into the output port.
- Only the cathode for LED 0 is grounded.

■ FIGURE 8. Pinout of the four-digit LED display.



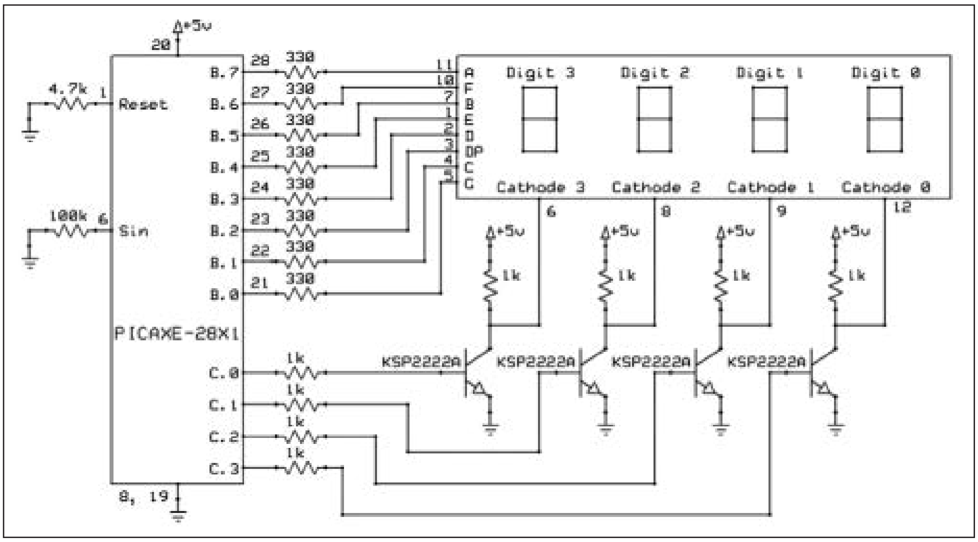
When this sequence is executed rapidly enough, all four digits appear to be displayed simultaneously.

The schematic for our four-digit multiplexed display experiment is presented in **Figure 9**; the Parts List is in **Figure 10**; and the breadboard layout for the experiment is shown in **Figure 11**. (In the breadboard photo, the board to the right of the College Board is a simple four-switch stripboard with which I have been experimenting. It's not connected in any way to our current experiment, so just ignore it.)

Keeping the above sequence in mind, let's take a look at the schematic (see **Figure 9**) to see how the display multiplexing is implemented. Similarly to the single-digit display, eight outputs are connected (through current-limiting resistors) to the display segments. (The order of the connections differs from that of our first experiment, again to simplify the breadboard wiring.) The necessary hardware would be simpler if we could directly connect four outputs from Port C of the 28X1 to the four common cathode (CC) pins of the display.

However, when all eight segments are powered, the current flowing through the CC pin is approximately 80 mA, which far exceeds the maximum current capability of any PICAXE I/O pin (see **Figure 6**). Therefore, we're using NPN transistors as switches to protect the 28X1 I/O pins from the excessive current draw.

As you can see, the circuitry for each transistor is identical. Let's look more closely at the transistor switch connected to the C.0 output to see how it functions. The standard symbol for an NPN transistor includes a small triangle pointing away from the base at the emitter connection. When using a transistor as a switch (NPN or PNP), the general rule is that the switch will turn on whenever the base is taken toward the collector. In our schematic, each of the collectors is tied high through a 1K resistor. Therefore, when the base is low, the transistor switch is off and the corresponding CC pin

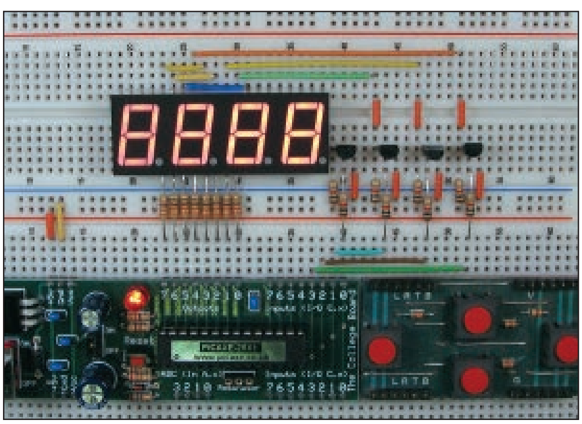


■ FIGURE 9. Schematic for the four-digit LED experiment.

is also held high by the same 1K resistor. Furthermore, when the CC pin is high, no current will flow through any of the segments of the corresponding LED, so it will be blank.

Conversely, when the base is pulled high the switch is turned on and the corresponding CC pin is connected to ground, which means that the corresponding LED will display the value specified by the data being output on Port B. To summarize all this: A high on a Port C pin turns on the corresponding display LED; a low on a Port C pin turns off the corresponding display LED.

Since the Port B output pins are connected to the display segments in a different order than they were in our first example, we need a new data table for the binary-to-decimal conversions. **Figure 12** presents the necessary data. To fill in the entries in the "Binary Value" portion of the table, I arranged the segments at the bottom in the order that they are connected to Port B of the 28X2. I then just placed a "1" wherever a segment needed to be lit and filled the remainder of the cells with "0." Finally, I converted the binary values to the corresponding decimal values. (Actually, I cheated by using an Excel formula for this purpose!)



■ FIGURE 11. Breadboard setup for the four-digit LED experiment.

The program to drive our multiplexed display (LED7X4) is a little more complicated than that of our first experiment. In order to facilitate the following discussion, download it from the *N&V* website, open it in ProgEdit, then select Options > Editor from the Menu Bar and place a check in the "Display Line Numbers" option. That way, when you print out a copy of the program it will include the line numbers to which I will be referring.

To begin with, I want to clarify the two directives in lines 22 and 23, because I don't think I have used them before. (If I'm repeating myself, forgive me — I'm old!) You may have noticed that it takes a fair amount of time to download a program to the 28X1. The compiler actually makes three separate passes: one to download the program; one to download EEPROM data (even if there is no EEPROM or data command); and one to download Table data — again, even if there is no Table command. (We haven't covered Tables yet, but we will one of these days!)

PICAXE-28X1 Processor
LED, Four-Digit 7-Seg. Display
Eight Resistors, 330, 1/4 watt
Eight Resistors, 1k, 1/4 watt,
One Resistor, 100k, 1/4 watt
One Resistor, 4.7k, 1/4 watt
Four Transistors, KSP2222A

■ FIGURE 10. Parts List for the four-digit LED experiment.

The "#no_data" and "#no_table" directives cancel the two extra passes that the compiler makes and greatly reduce the program download time. To see what I mean, "comment out" the two directives (by simply adding a single quote or semicolon in front of each one) and compare the resulting download time.

The "dirsC" instruction in line 30 configures all the Port C lines as outputs. (Even though we're only using half of them, there's no harm in defining the others as outputs, as well.) In essence, the main loop in the program is similar to that of our first experiment — it simply counts in an infinite loop, but this time the count is from 0 to 9999. The potentially most difficult part of the program is accessing the four

■ FIGURE 12. Binary/Decimal output values for the four-digit display.

Displayed Digit	Binary Value	Decimal Value
0	1 1 1 1 1 0 1 0	250
1	0 0 1 0 0 0 1 0	34
2	1 0 1 1 1 0 0 1	185
3	1 0 1 0 1 0 1 1	171
4	0 1 1 0 0 0 1 1	99
5	1 1 0 0 1 0 1 1	203
6	1 1 0 1 1 0 1 1	219
7	1 0 1 0 0 0 1 0	162
8	1 1 1 1 1 0 1 1	251
9	1 1 1 0 1 0 1 1	235
Outputs	7 6 5 4 3 2 1 0	
Segments	A F B E D DP C G	

individual digits in our counting variable ("value"). Fortunately, PICAXE BASIC includes the math function "dig" which greatly simplifies this task.

For example, consider line 38 in the program: digit3 = value dig 3. Digit3 is a variable that was declared at the top of the program to store the value of digit #3. Here, we're using the standard digit numbering convention which identifies the right-most digit as digit #0, with the identifying numbers increasing as we move to the left. Therefore, digit3 stores the left-most digit in our four-digit counter variable. In line 38, we're instructing the compiler to pick digit #3 out of "value" (our four-digit counter) and store it in the variable "digit3" — lines 44, 50, and 56 accomplish the same task for the other three digits of the counter variable.

Let's examine the remainder of the program lines that process digit3 (lines 39-42). Once we have stored the value for digit3, we can look up the decimal value of the segment pattern that needs to be lit (see line 39). Notice that you can use the "digit3" variable in both places in the lookup command — in effect, the command updates digit3. For example, if digit3 started out as 0 the lookup command changes it to 250, which is the decimal equivalent of the necessary segment pattern for 0. The rest is easy: Line 40 turns off the four transistor drivers so that the display is temporarily blank; and line 41 updates the output port for the new display value (250, to display "0"); and line 42 turns on the transistor that is connected to the digit #3 CC pin so the "0" is actually displayed on LED #3. The remaining three groups of instructions carry out the same process for each of the other three digits.

When I originally wrote the program, I didn't include the commands that turn off the four transistors in lines 40, 46, 52, and 58. As an experiment, "comment out" those four lines, download the program again, and watch what happens. See if you can figure out what's causing the problem.

The inner for...next loop (lines 36 and 62) is only there to slow down the counting process. If you want to see how fast the 28X1 can count, comment out those two lines and download the program again. As an experiment, I did just that and timed how long it took to complete the count from 0 to 9999. According to my calculations, the result (two minutes and 12 seconds) is equivalent to approximately 1,600 instructions per second (based on 21 instructions per iteration of the do...loop). For even greater speed (approximately 4,000 instructions per second), you could install a 20 MHz external resonator and add the necessary "setfreq" command.

SO, WHO NEEDS A MAX7219, ANYWAY?

At this point, we seem to have accomplished our goal. The 28X1 is certainly able to drive a beautiful, flicker-free four-digit LED display, so why do we need the MAX7219 driver chip? The answer is that our current approach needlessly ties up the 28X1's processing power because it's always busy running the loop that keeps the LEDs properly illuminated.

For a relatively simple program, you could probably intersperse the necessary commands throughout the scanning loop, but more complex programs would be likely to result in display flickering, and or at least in the loss of timing accuracy. This is where the MAX7219 can be extremely helpful.

In the next Primer column, we'll take an approach similar to that of our recent LCD project and develop a serially interfaced four-digit peripheral LED display that can be used in all our PICAXE projects, even with the humble little 08M. See you then. **NV**

Check the *Nuts & Volts* website at **www.nutsvolts.com** for accompanying downloads. Check Ron's website at **www.jrhackett.net** for items from the Parts Lists.

ELECTRONET

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■ BY LOUIS E. FRENZEL W5LEF

COOL CHIPS CHARGE COMMUNICATIONS

New Integrated Circuits Make Wireless Easier

The one thing that has made wireless so easy to implement everywhere is the integrated circuit. The single chip radio transceiver is a common device and it is available in many forms to give us the huge number of communications options we have today. Semiconductor technology is giving us more and better chips than ever. Circuit geometries of 90, 65, and even 45 nm are becoming common today making the chips smaller, faster, and operational at ever higher frequencies. Along with that comes lower power consumption that enables battery powered portable devices to last longer with each charge. In case you don't follow the new devices, here is a look at some of the newer ICs that make wireless more desirable than ever.

HD RADIO IN THE NEW ZUNE

You have probably heard of Microsoft's MP3 player called Zune. Its sales do not match Apple's leading iPod, but it is a popular device. The latest model called the Zune HD has a feature that no other MP3 player has: HD radio.

Recall that HD radio is the digital version of AM and FM radio. HD radio broadcasts or simulcasts a digital version of the programming of selected AM and FM stations nationwide. The digital version is overlaid in the same spectrum and provides an AM digital signal that has the fidelity of FM, and a digital FM version that provides the fidelity of a CD. The digital signals are also more resistant to noise, as well as multipath fading that is often a nuisance when you are driving out on the highway or in rural areas. A neat feature of HD radio is that it can also multiplex two or three additional broadcasts on the same frequency. Called multicast, this capability lets each station broadcast alternative programming without more spectrum. And it gives the listener many more choices.

■ FIGURE 1. Microsoft's new Zune HD music player uses SiPort's SP1010 chip to implement HD radio. It is the only MP3 player with this feature.

I think Zune HD is one of the coolest music players available (**Figure 1**). It has a 3.3 inch OLED touch screen and can be had with either 16 or 32 gigabyte Flash storage. It also has a built-in 802.11g Wi-Fi radio that lets you connect to nearby hot spots or access points. A built-in browser lets you access the Internet and download songs from Zune Marketplace that also offers movies you can watch on the screen.

While many MP3 players have an FM radio built in, only Zune has HD radio. This is made possible by a single HD radio chip made by SiPort. The SiPort SP1010 is a complete radio except for the audio amplifiers. It can receive analog FM, as well as HD radio in the FM band from 88 to 108 MHz. It can also receive HD AM reception in the 530 to 1,700 kHz band. A neat feature of this chip is a receiver for the US 162.4 to 162.55 MHz weather band, however, this is not implemented in the Zune. Multicast channel reception is provided. HD radio developed by iBiquity now includes new features like searchable content by music genre, pause,

rewind, and play functionality, the tagging of a song for future online purchase, and digital data services.

MOBILE TV

You can now get TV on your cell phone. Some of the larger carriers like AT&T, Sprint, and Verizon let you subscribe to video programming over their 3G networks. It works reasonably well if you don't mind the small screen. Yet, TV over the cell phone network has the downside that it can overload the network and reduce the number of voice calls it can handle if too many subscribers decide to watch videos.

The solution to this problem is over-the-air (OTA) TV. The problem however, is the conventional OTA digital TV that we have today was not designed for mobile operation. It assumes fixed TV sets and not something that could be moving at 60 mph or so. The solution is a new mobile TV system. We are going to have two of those here in the US: Qualcomm's FLO TV and the new ATSC M/H system addition to the current DTV system. Both services require that the cell phone or other mobile device have a separate, built-in TV receiver, leaving the cellular network out of it.

FLO TV is based on Qualcomm's MediaFLO technology. This TV system uses the recently abandoned UHF channel 55 on 716-722 MHz. It broadcasts a compressed video signal using coded orthogonal frequency division multiplex (COFDM) that is designed for mobile operation. The video is formatted for a 340x240 pixel LCD color screen at a screen rate of about 20 frames per second (fps). You can get up to 20 or so channels of music, sports, weather, and short programs.

The system is designed for cell phones with the necessary TV receiver. Such receivers can also be built into laptops and netbooks, or be packaged in USB dongles or mini-cards. Separate portable TV receivers like FLO TVs new personal TV device shown in **Figure 2** are becoming available using Qualcomm chips.

The FLO system gathers the content from many sources and consolidates it into a compressed and multiplexed signal that is sent to local mobile TV broadcast stations in major cities. The cell phones and portable TV devices have a 3G cell phone connection back to the station that provides feedback and channel change functions.

The US' digital TV standard was developed several years ago by the Advanced Television Systems Committee (ATSC). It transmits video and audio in compressed form via an amplitude modulation (AM) technique called 8-VSB (vestigial sideband). This is the OTA signal you receive on your HDTV set. It works well enough, but it was not designed for mobile service. Just recently, however, ATSC completed work on a mobile version called ATSC M/H for mobile/handset. M/H will transmit a version of the main television programming that will work better in a mobile environment.

The M/H version uses a different compression method and reformats the video for a 416x240 pixel LCD screen at a lower data rate. It uses additional error correction coding to make the signal more robust under multipath fading and Doppler variations. This signal is created from the current programming and multiplexed in with the regular HDTV broadcast. An M/H compatible receiver in a cell phone or other mobile device can decode and display it. No ATSC M/H service is available now, but we should be seeing some in 2010 and beyond.

One of several new receiver chips that will make OTA TV possible in a cell phone is the Analog Devices' ADMTV804 RF tuner. This IC has an internal low noise amplifier (LNA) front end, Zero IF or direct conversion mixers, and a complete fractional-N phase-locked loop frequency synthesizer for channel selection. The device covers the frequency range from 54 to 245, and 470 to 862 MHz. It will not only receive the forthcoming ATSC M/N OTA signals but is also compatible with most other world mobile TV standards. And there are lots of them, including: Digital Video Broadcast-Handset (DVB-H) in Europe; Integrated Service Digital Broadcasting-Terrestrial (ISDB-T) in Japan; Terrestrial-Digital Multimedia Broadcast (T-DMB) in Korea; China Mobile Multimedia Broadcast (CMMB) in China; and several others. It has a low drop-out regulator and components for antenna matching built in to save on external discrete components. All this is in a 4 x 4 mm package.

ISM BAND WIRELESS

Lots of products use the unlicensed industrial scientific medical (ISM) FCC bands to transmit coded signals. Some examples are automatic meter reading (AMR), home and industrial automation, security systems, remote keyless entry, two-way telemetry, toys, and a whole slew of other things. The device that makes these work is a tiny radio transceiver used in conjunction with an embedded microcontroller.

One of the newer ISM radio chips is the TRC105 made by RFM in Dallas. It covers the 300 to 510 MHz range that hits several of the US Part 15 ISM frequencies. The chip uses on-off keying (OOK) — a type of AM or frequency shift keying (FSK). The data rate can be up to 32 kb/s with OOK, and up to 200 kb/s with FSK. The receiver has a great sensitivity figure of -112 dBm while transmit power can be as high as 13 dBm. This gives the transceiver an excellent range if the antennas are high enough and in the clear. For those wishing to develop wireless devices using this chip, you can get one of the developer kits for $280 each. Several frequency band versions are

■ FIGURE 2. FLO TV's Personal Television set receives signals from transmitting stations on 716-722 MHz. Up to 20 or so channels of mobile TV are available. Qualcomm chips make it happen.

available (see **Figure 3**).

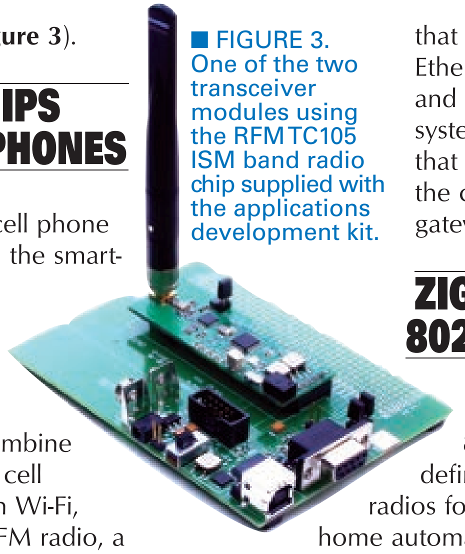
COMBO CHIPS FOR CELL PHONES

The hottest cell phone category today is the smartphone. The RIM BlackBerry and the Apple iPhone are the best examples. These phones combine an advanced 3G cell phone along with Wi-Fi, Bluetooth, GPS, FM radio, a camera, music player, and video. Squeezing all those different radios into a small handset is no easy job, but some of the new so-called combo chips are making it easier.

A good example is ST-Ericsson's CG2900 that uses 45 nm CMOS to put a Bluetooth transceiver, a GPS receiver, and an FM receiver (and transmitter) on a single chip. The GPS receiver has an amazing -163 dBm sensitivity that can latch on to the satellite signals even under the worst conditions. The CG2900 can also be used with the companion CW1100 IC which is a low power 802.11b/g/n WLAN Wi-Fi radio. Many Wi-Fi transceiver chips are power hogs, but this one uses significantly less power making it ideal for use in smart phones.

Another super combo chip is Broadcom's BCM6362. It combines an 802.11n Wi-Fi transceiver with an ADSL2+ modem. The modem is designed to implement the latest version of the digital subscriber line of high speed Internet connections in home routers and gateways. The ADSL2+ version can hit speeds up to 24 Mb/s downstream over twisted pair telephone cable up to 4,000 feet long. The 802.11n radio provides wireless connectivity to PCs and laptops.

But that is not all. This chip also includes the latest version of the popular DECT (Digital Enhanced Cordless Telecommunications) technology. The chip implements voice over Internet protocol (VoIP) for digital telephony over the Internet connection. Add to that a 10/100 Mb/s Ethernet port and switch, and you have a total system on a chip (SoC) that will greatly simplify the creation of single box gateways for homes.



■ FIGURE 3. One of the two transceiver modules using the RFM TC105 ISM band radio chip supplied with the applications development kit.

ZIGBEE AND IEEE 802.15.4 RADIOS

The IEEE 802.15.4 standard defines short range data radios for industrial and home automation and similar applications. It uses the 2.4 GHz ISM band and can transmit at a data rate up to 250 kb/s. ZigBee uses the same basic transceiver but adds a couple layers of software and a formal protocol to support mesh wireless connections that extend the range of a radio, as well as provide redundancy and reliability to the system. There are a number of manufacturers of ZigBee/802.15.4 chips but for many applications, the best approach is to buy a complete module ready to install. One of those module makers is California Eastern Laboratories (CEL).

CEL recently announced its new MeshConnect™ Extended Range Modules for 802.15.4/ZigBee applications. **Figure 5** shows one of the new modules that enable longer range (up to two miles) applications, as well as maintain robust mesh connections even in harsh, noisy, indoor RF environments. The new modules also deliver special features such as extended data rates and a built-in voice CODEC processor.

The extended range modules enable such new applications as intelligent control for LED lighting, in-hospital patient monitoring, baby monitors with two-way voice, and RF4CE — a new technology for RF-based TV and set-top box remote control.

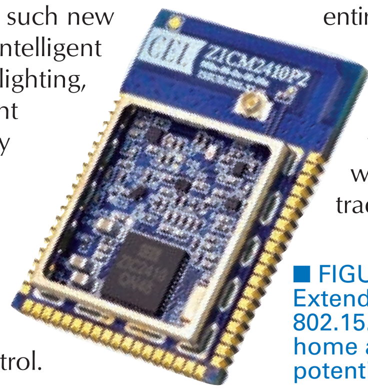
The ability to maintain RF links at long distances also enables applications such as large farm irrigation, wireless control for highway and street lighting, asset management with location tracking, enterprise security systems with video and voice, and wireless sensors in large industrial environments such as oil refineries and manufacturing plants

The secret to these module's performance is their superior +123.5 dBm link budget (-103.5 dBm receiver sensitivity and up to 20 dBm transmit power) that enables higher data rates to be maintained for longer distances. Even though these modules have higher power than shorter range modules, they have impressive battery life due to the extremely low <1 µA (microamp) sleep mode power consumption.

WI-FI ENHANCEMENTS

The Wi-Fi Alliance recently announced their new enhancement called Wi-Fi Direct for 802.11 radios. This is a feature that lets Wi-Fi transceivers talk directly to one another rather than communicate through an access point (AP) or hot spot. This new feature implements peer-to-peer communications that let devices connect to one another directly in a secure and intuitive fashion. Up to now that has not been possible. Chip company Marvell will be including that capability in it Wi-Fi chips in the future. This should extend the adoption of Wi-Fi in cell phones, games, personal media players, and other low power mobile devices.

Marvell also offers its Marvell Mobile Hotspot (MMH) — a fully functional 802.11a/b/g access point implemented entirely on a single low power chip. With this technology, battery operated consumer electronics can now function as full featured Wi-Fi access points while concurrently operating as traditional Wi-Fi clients. **NV**



■ FIGURE 5. CEL's MeshConnect™ Extended Range Module for 802.15.4/ZigBee applications in home and industrial automation. The potential range is up to two miles.

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ELECTRONICS

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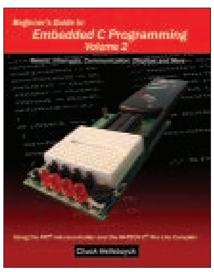

In this "Volume 2," Chuck takes the reader to the next level by introducing how to drive displays, how to use interrupts, how to use serial communication, and how to use the internal hardware peripherals of the PIC16F690 microcontroller such as SPI, PWM, and timers. When you have finished reading this book and completed the projects, you'll be well beyond the title of Beginner!

$39.95

The components that are added to the PICKit 2 that Chuck uses in his new book can also be purchased through the *Nuts & Volts* Webstore.

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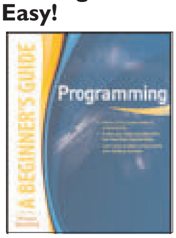
Programming A Beginner's Guide

NEW!

by Richard Mansfield

Essential Programming Skills--Made Easy!



This book will get you started right away writing a simple but useful program in Visual Basic Express Edition, and then moves on to more advanced projects, including a quiz program and a protected personal diary. You'll develop real-world programming skills, like designing user interfaces and working with variables, arrays, loops, and procedures. **$29.95**

Build Your Own Electronics Workshop

by Thomas Petruzzellis

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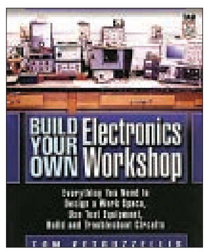

This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time!

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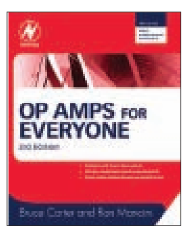

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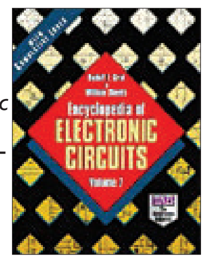

Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits, Volume 7*, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. Organized alphabetically by circuit type, this all-new collection includes the latest designs from industry giants such as Advanced Micro Devices, Motorola, Teledyne, General Electric, and others.

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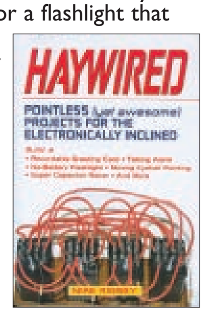
by Mike Rigsby



Construct a no-battery electric car toy that uses a super capacitor, or a flashlight that can be charged in minutes, then shines for 24 hours. Written for budding electronics hobbyists, author Mike Rigsby offers helpful hints on soldering, wire wrapping, and multimeter use. Each project is described in step-by-step detail with photographs and circuit diagrams. Includes websites listing, suppliers and part numbers.

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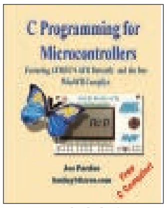
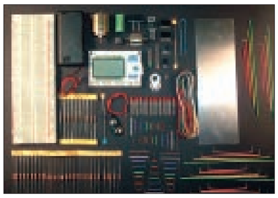


From the Smiley Workshop

C Programming for Microcontrollers

by Joe Pardue



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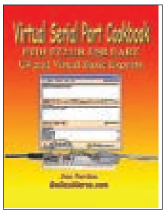

Virtual Serial Port Cookbook

by Joe Pardue

As talked about in the *Nuts & Volts* June issue, "Long Live The Serial Port"

Book **$44.95** Kit **$69.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Parts Kit and CD

(also *available, above right*)

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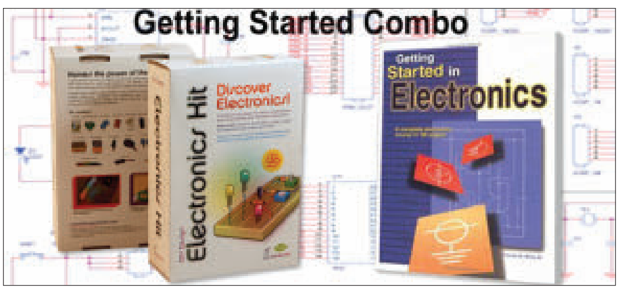

The Getting Started Combo includes: Getting Started in Electronics by Author Forrest Mims and the DIY Electronics Kit. In his book, Mims teaches you the basics and takes you on a tour of analog and digital components. He explains how they work and shows you how they can be combined for various applications. The DIY Electronics Kit allows for the hands-on experience of putting circuits together -- the kit has over 130 parts! No soldering is required and it includes its own 32 page illustrated manual. **Combo Price $62.95 Plus S/H**

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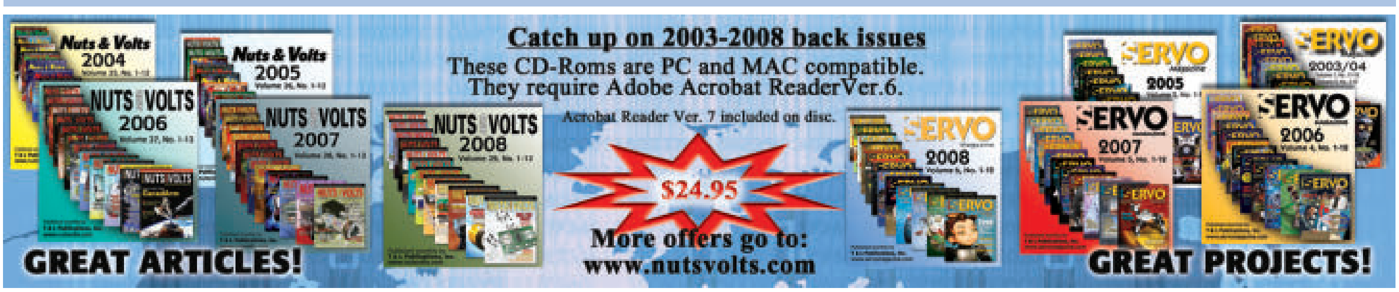

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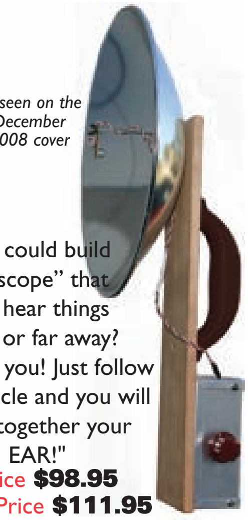
Big Ear Big Kit

As seen on the December 2008 cover



Ever wish you could build an "audio telescope" that would let you hear things that were faint or far away? Then this kit is for you! Just follow along with the article and you will see how to put together your own "BIG EAR!"

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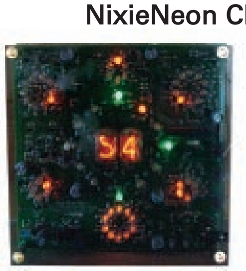
NixieNeon Clock Kit



Using Neon and Nixie bulbs, this clock displays the precision movement of time and is programmable to display "Time Chaos" at different intervals. The NixieNeon Clock then resets itself to the correct time in an eye-catching ballet of luminosity.
The PCB is 7.25"x 7.25" and consists of over 400 components.

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Transistor Clock Kit

If you like electronic puzzles, then this kit is for you! There are no integrated circuits; all functionality is achieved using discrete transistor-diode logic. The PCB is 10"x11" and harbors more than 1,250 components! For more info, see page 42, this issue.

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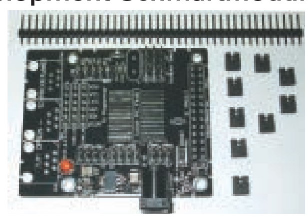

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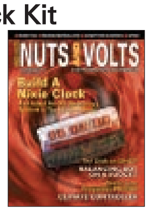

October 2006

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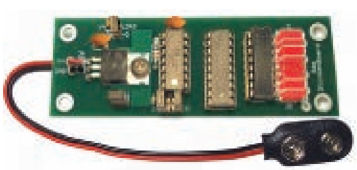

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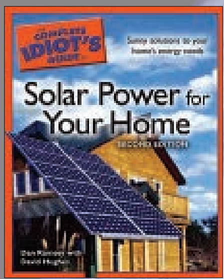

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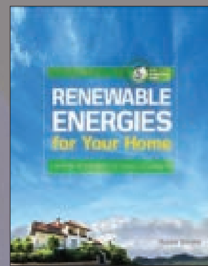

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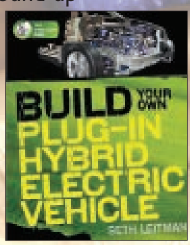

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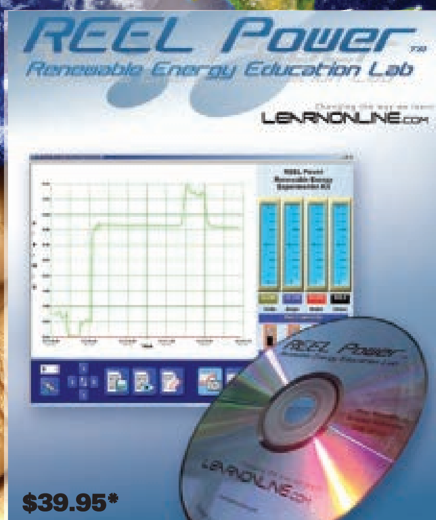

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by Carl Vogel

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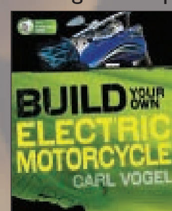

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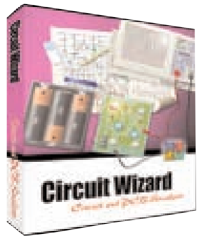

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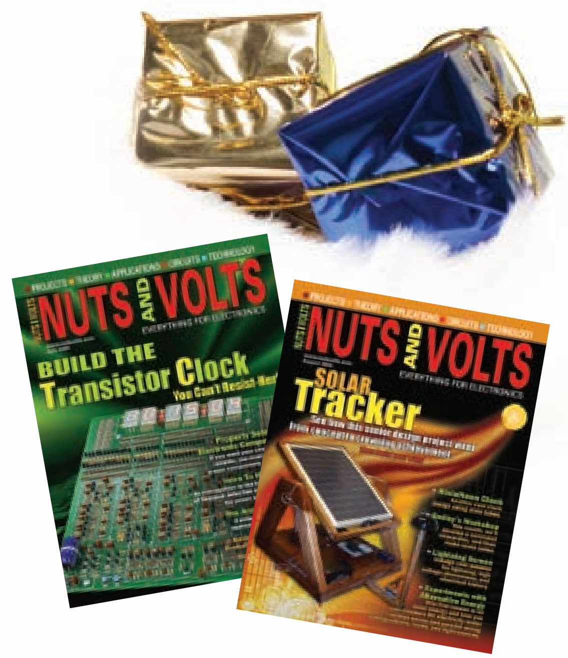

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>>> QUESTIONS

Audio Mixer/Summer

I'd like to build a circuit for the purpose of summing four separate audio signals into one line level output. In no particular order, the inputs would need to accept: a stereo line level auto, and a stereo auto from the head phone jack of my mp3 player. Preferably the gain would be set so the volume wouldn't have to be turned up to be heard. Lastly, I would like two mics (optional use), each needing their own adjustment for gain and level control.

#12091 **RCD**
Arcadia, FL

Computer Standby

I read the Oct 09 article on "The Green Standby" and was wondering if there is a circuit that would turn on or off all the cube powered equipment attached to my computer when it first gets turned on. Could this be accomplished by sensing a power level change when the start button is pressed or is there a better way?

#12092 **Peter Lowe**
via email

H-bridge/Relay for Trolling Motor

I'm designing a dual 12V, 50-pound-thrust trolling motor assembly for a small boat. It will run from 24V to achieve brief bursts of relatively high speeds on an engine-restricted local lake. I'll be using two independent PICAXE controllers for direction and speed control for each motor. I've already designed and tested the basic PICAXE controller circuits on small motors using a relay for directional control, and a PWM-driven bipolar on the ground side of the motor circuit for speed control. My questions are these: Should I use a semiconductor H-bridge or a relay to switch directions on the larger motors? I'm leaning heavily towards a relay for simplicity. Also, I need a part or circuit that can be driven with the PICAXE-level PWM signal and control the 12V motor (running from 24V) with an unknown surge current level (possibly over 100 amps per motor).

#12093 **David T. Bupp**
Carlisle, PA

Voice Phrase Toy

I want to embed four different short voice phrases that I'll record beforehand and load on to a device that plays them from pushing one of four buttons out of an eight ohm speaker. Can't seem to find a simple way to do that. Doesn't have to be as crazy as an mp3 player with LCD screens and LEDS, but it has to sound better than just generated tone on a piezo. Wondering if anyone has a schematic or something on the code to point me in the right direction.

#12094 **Greg Swizz**
San Diego, CA

Phone to PC

I would like to connect the line-out signal from my PC sound card to the handset jack of my office phone in order to record voice mail greetings that I have composed on a PC. Can a direct connection be made to the microphone terminals of the jack, or is an interface circuit required to match the signals?

#12095 **John Reynolds**
Rochester, NY

Transconductance Amp

Recently, the OP-27 op-amp has come up in some suggested preamps for VLF reception. I can find no cross-reference to this particular device, but it seems to have the same footprint as the old 741 and the newer CA3140. I would like to use this as a preamplifier for a low impedance untuned loop antenna for VLF. Since it will operate at low impedance in and out, does this come into the category of a "transconductance" amp as opposed to a voltage amplifier?

#12096 **John Seeley**
Palm Bay, FL

Lithium Polymer Batteries

It seems that the LiPo battery is all the rage these days but — outside of voltage and maybe current hour ratings — there are a number of other trailing numbers and letters in the specs that are unknown to the average person. I've even heard of some exploding. Can someone enlighten us a bit?

#12097 **Charlie Moher**
London, Canada

Fuses

I have a machine that calls for a 3.15A 125V slow blow fuse. Will a 3.15A 250V slow blow fuse be wrong? I can't find a 125V SB fuse. Do they still make them?

#12098 **Deb**
Orlando, FL

>>> ANSWERS

[#7094 - July 2009]
Microcontroller Circuit

I want to build a project using a BASIC Stamp 2p40 to allow me to reset pin setters at the bowling alley I work at from the front desk. I need a way to interface between the BASIC Stamp and the pin setters. The reset button is a 24 VAC circuit and I will be

Send all questions and answers by email to **forum@nutsvolts.com**
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connecting in parallel with the reset switch. I was thinking about using something like an opto-isolator but I want to be able to reset multiple lanes at the same time and am concerned because the Stamp can only sink 60 mA/eight pins, and from what I have seen in opto-isolators, they take 10 mA on the input. This would mean if I reset all lanes at the same time, I would need to sink 80 mA/eight pins. Am I going about this the wrong way?

#1 To interface your Stamp to your pin setter, you can use Avago ASSR-1411-001E solid-state relays connected to the Stamp pins through 820 ohm resistors. Current draw will be less than 5 mA per relay. The output side of these relays will handle up to 600 mA AC, and most pin setters use a recycle relay that will draw less than one tenth that. Verify that yours draws less than 60 mA. If space is a premium, you can use the ASSR-1420-002E which is a dual SSR — two complete relays in an eight-pin DIP package. The parts are available from Mouser.

Ed Schick
Harrison, NY

#2 You can save both money and I/O pin current by using 2N2222 transistors. Use a small five volt relay such as RadioShack p/n 275-240. Connect the relay between the transistor's collector and +5V. Be sure to use a 1N4001 diode across the relay coil (anode to positive) to prevent spiking your transistor. Connect the emitter to ground. You will use a resistor between the BS2p40 output pin and the transistor's base. If you use the 2N2222 transistor and the relay specified, you will find perfect results with a 2.2K resistor, which will limit your I/O pin current to approximately 2.3 mA. If you reset 30 lanes simultaneously, that's only 69 mA total for ALL the used I/O pins, or 18.4 mA per every eight I/O. If you need to use another relay or transistor, you will need to calculate the base resistor value to be sure you are driving the transistor to saturation. Contact me through **www.Xanatos.com** and I will provide you with the calculations to do so.

David Xanatos
Wilbraham, MA

[#8092 - August 2009]
SMPS Ripple Scrubber

What remedies might there be to further scrub the ripple from an otherwise very competent SMPS? As I am learning, simply throwing a farad or two worth of mondo blue caps between it and my headphone amplifier is not a remedy. I would like to stay outside of the unit itself. Any suggestions would be appreciated.

There are several ways to get rid of noise from an SMPS:

1. Filtering: LC and RC filters can be very effective. A good starting point is *The ARRL Handbook*. Although written primarily for harmonic filtering, filter tables can be easily scaled. Another good resource is the *Active-Filter Cookbook* by Don Lancaster, which explains normalizing and scaling fairly well. Almost all major semiconductor suppliers have filter design software (Filtercad, etc.) or some other design support. For example, Linear Technology has LT Spice IV which lets you read in a .wav file (your noise digitized with the sound card) and evaluate a filter design in SPICE.

2. Use of a linear regulator after the SMPS. Most three-pin linear regulators have suppression capabilities in the 80 to 100 dB range or more. This is a very effective broadband filter (10,000-100,000 to one attenuation). Allow for about a three volt drop for most standard regulators.

3. SMPS design can vary widely and therefore the noise can be either easy to remove or quite difficult. A fixed frequency SMPS should be the least troublesome. There are also fairly quiet, well designed ones available.

Walter Heissenberger
Hancock, NH

[#8093 - August 2009]
Battery Powered Hand/Foot Warmer

I help coach a high school ski racing team. As a consequence, I spend a lot of time standing in the snow and my hands or feet sometimes get cold. I would like to have a circuit to build a battery powered hand/foot warmer. Ideally, the circuit would regulate the power output of the resistor to maintain a preset temperature measured with a thermistor. The preset temperature point should be variable and able to be adjusted at any time. I plan to use four AA NiMH batteries in series.

The circuit shown in **Figure 1** will have all the desired functions and does not require any expensive parts. U1 is a Texas Instruments precision shunt regulator for 2.5 volts and provides a well-regulated and temperature stabilized voltage. This voltage drives an adjustable divider to provide the reference voltage for the inverting input of U2. D2, a 1N4148, serves as a low cost temperature sensor with about 500 mV voltage which drops by

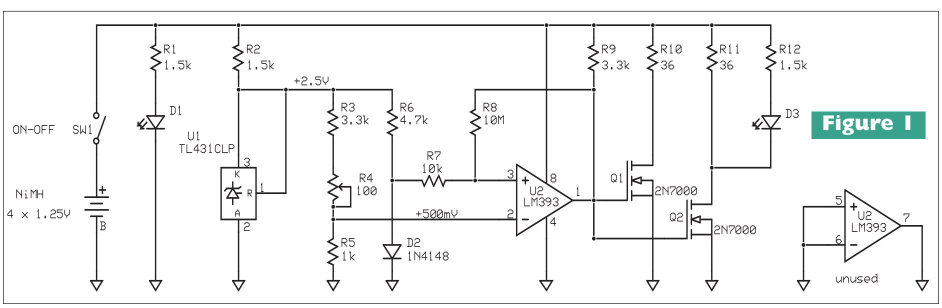

Figure 1

2 mV per degree Celsius. R7 and R8 prevent unwanted switching by adding a small amount of hysteresis. Two 2N7000 serve as the output stage, and turn the heaters R10 and R11 repeatedly on and off. D1 and D3 are high efficiency LEDs and show the various operating states. R3, R5, and R8 may need to be adjusted slightly to get the desired result.

Walter Heissenberger
Hancock, NH

[#8095 - August 2009]
Heart Rate Monitor

I need to build a heart rate monitor to see when my wife's heart rate gets too high. I have the standard finger model, but I would like something that uses chest probes and I could record the actual signal.

What is a circuit that will receive just the pulse data from a sports monitor's chest strap I can use to front-end a PIC to record and save data?

#1 To build a heart rate monitor, you will need an instrumentation amplifier. Dr. Shawn Carlson, founder of the Society for Amateur Scientists, has written two articles on how to construct an EKG circuit based on the AD624 instrumentation amplifier. The first, "Home is Where the ECG Is," can be found in the June 2000 issue of *Scientific American*. The second, "DIY ECGs," can be found in *Make Magazine* Vol. 11. Given that the amplitude of a heart signal is about 1 mV and the gain of the AD624 instrumentation amplifier is 1,000, the output voltage will be about 1V. If you want to view this on an oscilloscope, a signal amplitude of 1V is probably insufficient given the resolution of most oscilloscopes. Therefore, you must augment the design with a second stage which will take the form of a non-inverting amplifier (a 741 op-amp works well) with a gain of 4-5. This will make the signal easier to analyze on a screen. Chest electrodes can be bought in bulk from eBay. 3M Red Dot electrodes feature a protruding "nipple" to which alligator clips can be attached. Building a heart rate monitor from scratch may prove more feasible than trying to get a microcontroller to "talk to" a commercial monitor.

Erik Zavrel
Kenmore, NY

#2 Ramseyelectronics.com has a nice electrocardiogram kit, part number ECG1C. It requires three electrodes connected to the skin via stick-on patches. The output has both an analog heart waveform and an LED which blinks with each heartbeat. It should not be too hard to compute the heart rate in beats per minute by interfacing a PIC to the LED, maybe via an opto-isolator wired in series with the LED.

I built one of these kits and found that the patches are something of a nuisance; they lose their "stick" and the kit as supplied has little crocodile clips to connect to them. Professional quality ECG electrodes are available on eBay but I have not tried any.

Roger Hartop
via email

[#8096 - August 2009]
RFID

I have a small project that involves using an RFID transmitter chip and receiver, and I'm having trouble finding a source for small quantities of parts. For testing purposes, I only need one or two transmitters and one receiver. I'd like a reception range of about 2-3 feet. Application notes would also be helpful.

If you keep your *Nuts & Volts*, then the back issue of the July '07 issue has the Parallax ad with the RFID reader module and an assortment of transponder tags; **www.parallax.com** will get you current pricing and availability. Also search the site for "RFID" to find information. Don't forget that RadioShack is stocking Parallax products. My local RS has the RFID kit in stock (276-032).

Steve Benson
New Castle, IN

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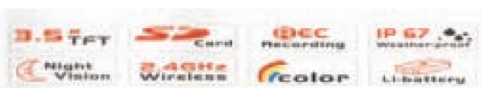

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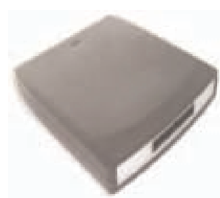
34 Channel USB Logic Analyzer



The CSI5034 is a sophisticated, portable, and easy-to-use 500MHz, 34-channel logic analyzer equipped with features found only in more expensive bench type instruments. Using advanced large-scale integrated circuits, integrated USB 2.0, CPLD, FPGA, high-frequency digital circuitry, embedded systems, and other advanced technology, make the CSI5034 your best choice in pc-based logic analyzers The CSI5034 is suitable for electronic measurement engineers, college students in scientific research and development and teaching assistants.

- 34 input channels capable of simultaneously monitoring data and control information, and is capable of capturing narrow pulses and glitches that may be missed by other test equipment.
- Delay feature provides the ability to capture data around the waveform, both before and after the desired trigger signal. This allows the operator to view the data at multiple points in the data stream
- Memory feature stores multiple data points for error analysis of the unit under test and to aid in locating defective components.
- Intuitive and flexible viewing screens to facilitate analysis of the system under test. Data can de displayed as binary, decimal, or hexadecimal values.
- Can be triggered in a variety of ways (rising edge, falling, edge or both) , and also has an advanced trigger function that allows logic operations to be performed on the data before a trigger is generated. This provides the ability to trigger on a specific data byte or word from any of the monitored channels.

NEW ITEM Item # **CSI5034** **$329.00**

Premium All-In-One Repairing Solder System

The BlackJack SolderWerks BK6000 Repairing System is a digital multipurpose reworking system that incorporates a Hot-Air Gun, Soldering Iron, (compatible with leaded solder or lead free solder), with integrated smoke absorber and a desoldering Gun.

Item# BK6000 **$199.00**

Hot Air System w Soldering Iron & Mechanical Arm

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air & soldering in one compact package. The hot air gun is equipped with a hot air protection system providing system cool down & overheat protection.

Item# BK5000 **$119.00**

Hot Air with Vacuum I.C. handler & Mechanical Arm

The BlackJack SolderWerks BK4050 is designed to easily repair surface mount devices. Its digital display & tactile buttons allows easy operation & adjustments. The BK4050 includes a hot air gun and a vacuum style I.C. handler.

Item# BK4050 **$119.00**

Thermostatically controlled desoldering station

The BlackJack SolderWerks BK4000 is a thermostatically controlled desoldering station that provides low cost and solid performance to fit the needs of the hobbyist and light duty user. Comes with a lightweight desoldering gun.

Item# BK4000 **$119.00**

Digital Display Solder Station for Lead Free Solder

The BK3000LF is a compact unit designed to be used with lead free solder that provides reliable performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

Item# BK3000LF **$74.95**

Compact Digital Display Solder Station

The BK2000+ is a compact unit that provides reliable soldering performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

Item# BK2000+ **$56.95**

Compact Soldering Station

The BlackJack SolderWerks BK2000 is a compact unit that provides reliable soldering performance with a very low price. Similar units from other manufacturers can cost twice as much. A wide range of replacement tips are available.

Item# BK2000 **$36.95**

Close Focus Small Spot Size Infrared Thermometer TN01U

ZyTemp

Featuring spot-on, dual-laser aiming, the TN01U close-focus, non-contact IR thermometer measures the temperature of electronic components as small as 0.1-in. with pin-point accuracy. Compact and lightweight, the instrument provides a large LCD and a bright dual-laser aiming system that allows for accurate aiming. Features include a measurement spot size of 2.5-mm in diameter at distances up to 18 mm, measurement range from -55ºC to +220ºC,(-67-428 deg F) an accuracy of ±2% of reading or ±2ºC whichever is greater, a repeatability of ± 0.2ºC, display resolution of 0.1ºC, and a response time of 1s. Operating with two AAA batteries providing 18 hours of continuous use, the instrument measures. This is the most advanced infrared thermometer manufactured today providing fast, accurate, non-contact component temperature measurements for hardware designers, Test, QA and Service professionals.

SALE **Item # TN01U**

Regular Price $129.00

$89.00

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage & current outputs. Short-circuit & current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance & long life. All 3 Models have a **1A/5VDC Fixed Output** on the rear panel.

Item #:	Price 1-4	Price 5+
CSI3003X-5 0-30V/0-3A	$119.00	$112.00
CSI5003X5 0-50V/0-3A	$127.00	$119.00
CSI3005X5 0-30V/0-5A	$129.00	$122.00

Temprature Controlled Reflow Oven

The HHL3000 Reflow Oven is a highly versatile tool used for reflowing and preheating different surface Mount technology (SMT) components and printed circuit boards (PCB's). The system utilizes a microcontroller to effectively amd efficently manage the working temperature while facilitating the duration of the heating process. A bright LED display clearly displays the time and temperature along with a fully digital control panel for ease of use and monitoring.

The HHL3000 makes use of infrared (IR) heat wave technology to distribute heat evenly on the component and PCB. Included is an integrated temperature sensor that allows positioning in such a way that the measurement of the actual temperature of PCB and components can be obtained. This minimizes damage to the PCB and its components due to thermal shock or low level temperature conditions.

FUNCTIONS and FEATURES

* Microprocessor-controlled equipment.
* Direct PCB temperature measurement, improves accuracy and lessens damage or distortion.
* Five (5) temperature and time control points with automatic slope adjustment. Configurable to suit different solder paste and circuit boards.
* Two (2) default profiles suitable with most common solder paste specifications.
* Quick and easy resetting of control points for precise tuning of reflow profiles.
* Built-in safety feature of industry standard 0.01°C/s to 3°C/s rising slope.
* Fully digital panel controls and read-out of time and temperature for monitoring and ease of use.
* Highly compatible with lead-free applications.

Item# HHL3000 **$949.00**

3 in 1 FOCUSED Infrared Soldering/Repair System

The CSI720 Three in One Focused Infrared Welding System generates heat through a concentrated infrared heat wave, providing precise soldering without movement of surrounding components.

ESD Safe, Focused Infrared Welding Station For reworking BGAs, micro BGAs, QFPs, PLCCs, SOICs, small SMD and other circuit board components. Unit produces a concentrated infrared heat wave, for precision soldering. Infrared soldering eliminates movement of surrounding components, and marks on reworked PCB's, both associated with standard hot air gun reworking.

3 in 1 Repairing System Combines the function of an Infrared Welding Tool, Soldering Iron and Pre-heater.

Full Digital Control with LED Displays Allows precision setting of welding temperature & time, soldering iron and pre-heating temperatures.

Closed loop temperature control For instant and precise process adjustments.

Adjustable Infrared Tool Post Stable and adjustable Infrared welding tool holder for increased precision soldering and hands free operation.

Adjustable Eye shield & Welding Goggles To protect users from harmful light rays.

Uses infrared heat wave technology instead of the conventional hot air, effectively solves the major problem being encountered when using the hot air gun, which is the movement of surrounding components while reworking.

Item # CSI720 **$1,399.99**

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA

Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	$198.00	$193.00
CSI3005XIII 0-30Vx2@5A	$259.00	$244.00